



PESTICIDES AND HUMANITY: THE BENEFITS OF USING PESTICIDES

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EXECUTIVE SUMMARY

The overwhelming majority of publicly available publications on pesticides take a negative position. This is no surprise since the benefits seem self-evident – they kill pests - whereas the hazards are unintended and therefore of greater academic and journalistic interest.

In order to inform a more balanced view, this study was carried out to identify and characterise the various types of benefit and where possible find publications to support them. There is no attempt in this report to weigh the benefits of pesticides against potential risks – that would represent a much bigger task.

The source information assembled during the preparation of this report can be consulted through the dedicated CropLife Benefits Database, which can be found at (http://www.croplifefoundation.org/international_benefits_db.asp). This database allows the user to search on a range of criteria for published evidence of various types of benefit arising from pesticide use. A short abstract and the bibliographic reference for each publication can be accessed from the web pages and for in-house users, the full text document can be downloaded.

In addition to identifying the immediate consequences – here referred to as pesticide effects (essentially examples of pesticides killing pests) - the report tracks through to primary benefits such as increased yield and then to less intuitively obvious secondary benefits, for example reducing the emission of greenhouse gases because using herbicides is less energy intensive than the mechanical cultivations required to achieve an equivalent effect, or slowing down rural-urban migration in the developing world by making agriculture a better livelihood option. In some cases these secondary benefits are what ultimately justify the pesticides' use. The primary and secondary benefits can be further categorized as economic, social or environmental (see Appendix 1), but this is not the way this analysis is structured. Rather, it is structured on the basis of the three main pesticide effects, since we consider this more user-centred.

Where there are benefits, it follows that there are individuals or groups of people who gain, i.e., the beneficiaries. The report considers who stands to gain from different types of pesticide use, such as farmers, consumers, local communities, commerce, the global environment or mankind generally.

The finding from the study is that the list of beneficial outcomes from sensible use of pesticides is long and provides compelling evidence that pesticides will continue to be a vital tool in the diverse range of technologies that can maintain and improve living standards for the people of the world.

INTRODUCTION

The hazards of pesticides are well documented. A recent brief survey of pesticide-related articles produced a ratio of over 40 negative for each one with a more positive viewpoint. Some take the line that organic agriculture has survived successfully for centuries and should therefore be the basis of modern productive agriculture. A host of others point to health problems from accidental or deliberate exposure to pesticides. Such occurrences are recognised, but this report focuses on the other, rather neglected side of the coin, that is the ways in which pest management chemicals make a positive and often essential contribution to society.

Most people eat food grown in a system that uses pesticides and many individuals use pesticides in the house or garden. In places where there are insects whose bites can be a nuisance or a hazard, insecticides are used to make life safer or more comfortable. Yet there is little acknowledgement of the important beneficial role that pesticides play in US and European agriculture, or in parts of the world where flies and other arthropod vectors spread dreadful diseases (WHO, 2004). Why then the paucity of independent published material underlining their useful role? One reason is that scientific literature is partially blind to the benefits since peer-reviewed scientific reports have to be innovative, and when a product does exactly what the manufacturer says it does, it is not newsworthy. No one publishes scientific papers on the wonders of gloss paint, but it remains a good way to protect exterior woodwork.

Some authors do value the beneficial role of pesticides. Lomborg (2001) said "If pesticides were abolished, the lives saved would be outnumbered by a factor of around 1000 by the lives lost due to poorer diets. Secondary penalties would be massive environmental damage due to the land needs of less productive farming, and a financial cost of around 20 billion US Dollars". Denis Avery (1999), Director of the Centre for Global Food Issues at the Hudson Institute in the US wrote in the Wall Street Journal "Humanity in the 21st century can banish hunger, end nutritional deficits in its children, and save virtually all of the remaining wild lands in the process. But there are only two ways to do it: either murder four billion people, or use chemicals and biotechnology to maintain and increase yields on land already under farming".

Way and van Emden (2000), called for integrated pest management practices that include pesticides, but make use of host plant resistance and biological and cultural controls to minimize harm to natural enemies and to the environment. They anticipated that appropriate conventional synthetic insecticides will remain as important IPM components in many crop systems for the foreseeable future, and gave examples to illustrate mechanisms (differential selectivity, timing, decision thresholds) by which pesticides can be integrated into control programmes that involve alternative methods.

The risks and negative aspects associated with obsolete or wrongly managed pesticides should not be ignored, but nor should the positives. This report is a way of redressing the balance through an objective assessment of the published evidence of their beneficial role in our lives.

Benefits and risks

Before embarking on the analysis of benefits, it is worth remembering that most people are poor judges of relative risk. Based on earlier US data by Upton (1982), Hibbitt (1990) ranked 30 hazards on the criteria of number of deaths per year. Pesticides were ranked 28. By contrast, adult women's perception was that they ranked number 9. College students put them at number 4. Both groups were off target and wildly over-estimated the risk posed by pesticides. To illustrate the balance of risk and benefit, Berry (1990) pointed out that the valuable analgesic drug paracetamol was sold over the counter in packets of five lethal doses, yet we accept the risks of people misusing paracetamol due to the convenience of such easy access to pain relief.

The decision-making process made by pesticide registration authorities must balance potential risk to humans and the environment against projected economic, social, and environmental benefits. In certain instances, risks may be so great that benefits of any kind may not outweigh them. The pesticide would therefore not be registered for use (EPA, 2004) and in practice manufacturers would not even proceed to development, as the extensive screening procedures would have removed them from their development process. In other situations, risks are low or manageable, but the general public may not always possess the information to enable them to make an objective judgement and they therefore often exhibit unfounded bias. In addition, people have become highly sensitive to many health and food issues following serious incidents such as Salmonella poisoning, BSE and Foot and Mouth disease infections, but there is no reason to regard pesticide residues in food as representing the same type of risk. The UK Pesticide Residue Committee annual report (2002) showed that over 70% of the food in the UK contained no pesticide residues at all and only 1.09% contained residues above the statutory maximum residue levels (MRLs). It concluded that "none of these residues caused concern for people's health". John Bell, Head of the UK Food Standards Agency, a body that was set up to restore public confidence in food said (2005) that "Maximum residue levels are generally set well below safety limits. There are no safety concerns or we would take action immediately." Yet these very small quantities of chemicals in our food, detected at ever lower levels due to increasingly sensitive laboratory equipment, are now easy targets for the media, despite overwhelming evidence that residues pose a very tiny risk to the people who eat farm food (Brown, 2004, US EPA), a risk that is anyway far outweighed by the benefits of a diet that includes fresh produce.

Many people now rightly expect and enjoy a healthier and longer life than in the past and average life expectancy in the US, which was only 47 years in 1900 has now risen to 78 (Official statistics, anon, 2005). Most lives are also more comfortable in the 21st century than those experienced by our ancestors who tended to work hard and die young. Medical care and drug treatments with better living conditions and improved hygiene have played a significant role (The European Food Information Council, 2006), but the value of nutritious, varied and affordable food from local and overseas farms should not be underestimated as a health promoter (European Food Information Council, 2006). This is acknowledged by governments (US dietary

guidelines, 2005; The European Food Information Council, 2006; Eat 5 to 9 a day (US) and 5 a day campaign, UK, 2003).

Paradoxically many people in the west consume more food than they need and become overweight (UK Gov, 2004), which is a much bigger risk to health and longevity than risks posed by pesticide residues. However it would be wrong to let problems of obesity and excessive consumption prejudice attitudes to agriculture or demonise highly productive intensive farming – this is more an issue of education on healthy eating and lifestyle.

Like many technological developments that improve the quality of our lives, pesticides can pose some risks if they are not used with due care and consideration. In this they are not unique. We have to make many risk-benefit decisions throughout our lives. Cars kill over 40,000 people each year in the US alone (Official statistics, anon, 2006). Their emissions contribute to greenhouse gases (Anon, 2006) and they are inefficient users of energy (Sustainable energy coalition 1996) compared with alternatives such as buses or trains (Congressional report, 1977). However the convenience and value of being able to get around independently is enormous, so many of us buy and drive cars. To reduce the risks and negative aspects of car ownership we legislate to make them safer (Likanen, 2001), more efficient (New car, 1995) and less polluting (EPA, 2004).

Likewise mains electricity brings irresistible benefits but there are some negatives too. Its production pollutes the atmosphere and causes 33% of greenhouse gases (World Resources Institute, 2006). Accidents occur in mining (US Dept of Labor, 2006) and transportation of fuels, and each year there are injuries and deaths from accidental contact with high voltages (400 deaths in 2001 in the US alone according to the Product Safety Commission, 2006). Similar benefit versus risk balances need to be made with the use of medical drugs. Few people would deny that they are capable of reducing diseases and preserving life, but if they are used without care they can be extremely dangerous. These examples are therefore, like pesticides, technologies that make our lives better as long as the benefits associated with their use outweigh the manageable risks.

Our approach – categorising effects, benefits and beneficiaries

Tackling this study of the benefits of pesticides was an iterative process. Some of the benefits, such as the reduced mortality from malaria achieved by controlling *anopheline* mosquitoes, are obvious and we knew what we were searching for in the literature. However, the initial searches provided leads to different benefits. Some of these others are less obvious due to them being secondary benefits arising either in the medium or long term, or being subtle or small incremental benefits distributed over a very wide area. However, these secondary benefits are equally important and in some cases provide the ultimate justification for the use of the pesticides.

We also had to address the question of who is benefiting. The number and nature of beneficiaries determine our attitudes to particular categories of pesticide use. Clearly the farmer using herbicides is saving money or effort on mechanical weed control costs – a direct benefit to him. But there is an environmental benefit too in reduced

use of fossil fuels and reduced soil disturbance in no-till systems – representing a common good benefit to us all. Beneficiaries may be individual farmers, farming communities, businesses, regulatory authorities, researchers, national populations or the whole living world. There may also be a skewed distribution of benefits relating to wealth or geographic distribution and this is pointed out where relevant.

Critics of this document may claim that the stated benefits can be achieved without using pesticides, for example using cultural practices to control pests, leading to larger yields and higher quality of life. There are instances where this is true, but all of the cases given here are examples where pesticides HAVE delivered the stated benefits. It is for others to establish where there are better, alternative means of achieving the same end.

The best we can hope for is that the public makes informed choices about which technologies will be most likely to bring them the benefits they are seeking, at lowest cost to them, others and the environment. This document aims to provide evidence to guide and change these consumer attitudes and choices by putting the spotlight on the positive facets of pesticides. In so doing it should help to inform more objective decision-making.

In choosing our approach, we recognised that there were a range of types of benefit from individual types of pesticide use. For example, herbicides may bring benefits in a range of different areas, including financial (saving money because labour is expensive), physical (reducing drudgery of workers doing manual weeding), environmental (less use of fossil fuels in powered machinery, controlling weeds without disturbing the soil) and social (reduced drudgery, improvement of the living environment on public and personal-use amenity or sports-use land). We felt that structuring the report by types of benefit was more understandable and would make the report more user-centred.

In order to ensure a systematic analysis and to unravel the many potential benefits of pesticides, we developed a hierarchical model of outcomes, The categories of effects, and primary and secondary benefits outlined below are expanded later on in the text and summarised in Figure 1 and Appendix 1.

Effects

These are the immediate outcomes of pesticide use – for example killing caterpillars on a cabbage. These are not considered to be benefits in this report, because the results of these effects have not manifested themselves yet. The main effects are:

- Controlling agricultural pests (including diseases and weeds) and vectors of plant disease
- Controlling human and livestock disease vectors and nuisance organisms
- Preventing or controlling organisms that harm other human activities and structures

Primary benefits

These are the consequences of the pesticides' effects – the direct gains expected from their use. For example the effect of killing caterpillars feeding on the crop brings the primary benefit of higher yields and better quality of cabbage. The three main effects result in 26 primary benefits ranging from protection of recreational turf to saved human lives.

Secondary benefits

These are the less immediate or less obvious benefits that result from the primary benefits. They may be subtle, less intuitively obvious, or longer term. It follows that for secondary benefits it is therefore more difficult to establish cause and effect, but nevertheless they can be powerful justifications for pesticide use. For example the higher cabbage yield might bring additional revenue that could be put towards children's education or medical care, leading to a healthier, better educated population. There are 31 secondary benefits identified here, ranging from fitter people to conserved biodiversity.

Figure 1 summarises the effects, primary benefits and secondary benefits and their interactions. The interplay between the effects and benefits listed below is complex and not easy to follow in this diagram. However, for the moment, the detailed linkages are less important than the broad concept that there are many and varied positive downstream implications arising from pesticide use – some more obvious, and some less so. These are discussed in more detail later in the report and presented in Appendix 1 as a matrix that illustrates the individual linkages more clearly.

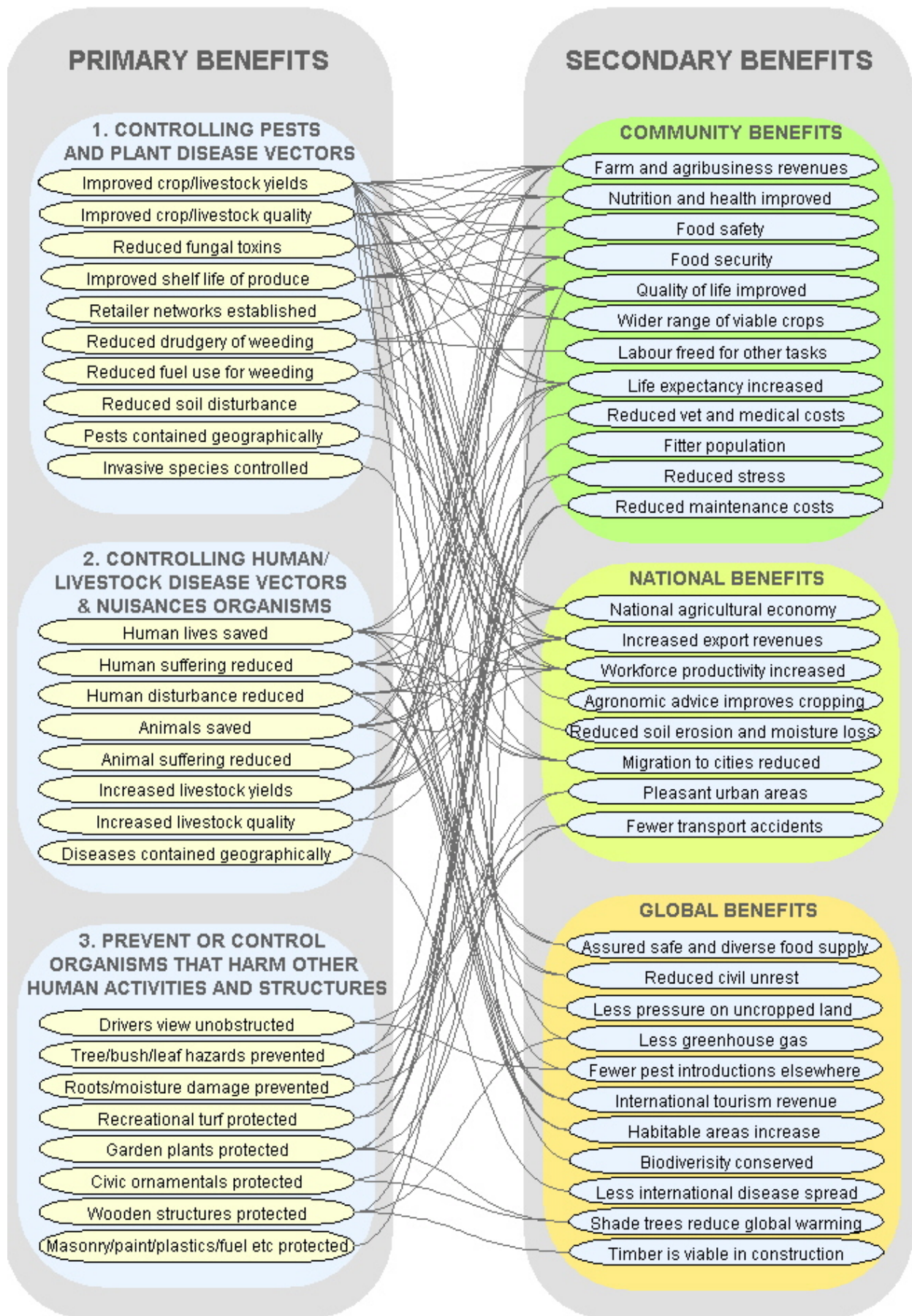


Figure 1. The benefits of pesticide effects – a summary of interactions

PESTICIDE EFFECT 1. CONTROLLING PESTS (INCLUDING DISEASES AND WEEDS) AND VECTORS OF PLANT DISEASE.

Context

Food production is crucial to everyone, but sustainable livelihoods based on farming are especially important for many of the world's poorest people (Christian Aid, 2002). Of the 1.2 billion living on the equivalent of less than US\$1 a day (WHO, 2003) about 75 percent live and work in rural areas and most rely on agriculture directly. These people cannot afford to have their crops ravaged or destroyed during production or storage. Moreover many of the poorest people are youngsters who are particularly susceptible to food shortages. UNICEF (2005) estimated that half of the world's children live in poverty and in the short-term at least, most of these people will continue to rely on farming for survival and a chance to escape from poverty. In the west we spend a much lower proportion of our income (12%) on food than in the past (USDA, 2005) in line with Engel's Law (Engel 1842) that as incomes rise, a smaller share of expenditures is devoted to food. In Africa and much of the developing world where incomes are lower, purchase of food dominates personal expenditure. Tanzanian families spend 71% of income on food, and in these tropical regions people and their crops are much more threatened by diseases, pests and weeds that affect their food supply. While it is true that some crops that are important to poor people, such as maize, cowpea, sweet potatoes, rice and sorghum, can sometimes be grown successfully without using pesticides, there are three important problems with this:

- the harvested yield is often chronically low due to pest damage
- there is a risk of occasional catastrophic crop failure
- produce quality may be low.

Pests cost developing countries billions of dollars in national income (FAO, 2004) and farm and post harvest losses contribute to hunger and malnutrition. Malnutrition kills between 12 million (UNICEF undated) and 15 million children annually (Think Quest, 2005). According to Carol Bellamy, Executive Director of The United Nations Children's Fund (UNICEF) malnutrition is: "largely a silent and invisible emergency, exacting a terrible toll on children and their families".

It would neither be logical nor ethical to expect poor people to forego the benefits of technologies used in the richer countries to grow and protect crops. The report Food Security and Sustainable Use of Natural Resources by Pinstrip-Andersen and Pandaya-Lorch (1998) concluded that certain measures are needed to achieve the International Food Policy Research Institute's 'Vision' in which every person has access to sufficient food to sustain a healthy and productive life, and where food originates from efficient, effective, and low-cost food and agricultural systems that are compatible with sustainable use and management of natural resources. These measures include the need for developing countries to have increased access to agricultural inputs such as water, fertilizer, pesticides, energy, research, and technology.

Overview of primary and secondary benefits of Pesticide Effect 1.

The use of pesticides can prevent or reduce agricultural losses to pests and so improve yield, as well as improving the quality of the produce in terms of cosmetic appeal – often important to buyers. They can also improve the nutritional value of food and sometimes its safety.

To resource-poor communities with no financial or food reserves, the reliability of production is also of paramount importance. It is no good having a good harvest for three years if there are large losses in the fourth year. There is a financial cost if pesticides have to be used, but at least there will be something left to harvest for sale and/or consumption. In this way, pesticides are a tool to deliver food security. Pesticides used in stored products can prolong the viable life of the produce and prevent huge post-harvest losses from pests and diseases.

These primary benefits bring many secondary benefits. Clearly if harvestable yields and quality are increasing, farm revenues are also likely to increase. This results in wealthier farmers with more disposable income to stimulate the local economy. In turn regional and national agricultural economies become more buoyant and revenues from exports of high quality produce bring in much needed foreign exchange. This last factor is particularly important in some developing countries that export out of season fruit and vegetables to the US and Europe. Consumers in developed countries gain too from the wider range of imported crops that is available for a greater proportion of the year. And higher yields mean less pressure to cultivate un-cropped land – a wider benefit to the environment.

Greater quantities of food in communities also generally means better nutrition, which carries over into better health. Healthier people are by and large also happier people, who are more productive and able to contribute better to their society. This contrasts with the situation where the poor nutrition resulting from limited food supplies increases the susceptibility to diseases, reducing people's energy and productivity in a vicious circle of deprivation. Pesticides can help break this cycle that also threatens the security of personal livelihoods and the economic well-being of affected regions.

Effective control of pests can have consequences beyond the geographic or chronological range of the initial intervention. If pest numbers are suppressed by many farmers at once, it can have an area-wide effect – in other words, the source population for infection or infestation of future crops is reduced. The threat to subsequent crops is therefore much lower, even without future interventions. This is dependent on there not being effective alternative hosts outside the cropped areas nor high pest mobility that allows rapid re-infestation from afar.

Even for more mobile pests such as locusts, early interventions can be more cost-effective than later 'fire brigade' action. If gregarious locust populations can be controlled before they breed in one country, it can prevent massive population expansion and migration to other countries (FAO, 2001). Also, pests controlled effectively on export crops can prevent pest introductions in other countries – something that often has devastating effects due to the fact that the new pest has

left behind all of its natural enemies, i.e., predators and parasitoids that were exerting a natural regulatory pressure on the pest in its native region (Neuenschwander, 2001). Pesticides are also a powerful tool against invasive species that constitute an enormous threat to indigenous ecologies. For example when rats are introduced onto islands previously free of them, they have a devastating effect on local fauna - in particular, on ground-nesting birds, but also other mammals, molluscs, insects, spiders, amphibians and reptiles. The presence of certain flora and fauna in produce destined for export can also be a barrier to international trade (IPPC, 1997).

Herbicides replace the back-breaking work of manual weeding, and reduce the fossil-fuel requirements for mechanical cultivation. The reduction in the need for manual weeding is particularly significant in sub-Saharan Africa where HIV/AIDS has resulted in shortages of labour and many adults being too ill to work (Hainsworth and Eden-Green, 2004, FAO undated). Moreover, what labour is available can be freed for other productive activities. The improved nutrition and reduced drudgery clearly improve the quality of life of rural communities. The notion of quality of life is imprecise and difficult to define, but it is surely what most people are seeking to improve – whether it be through money, work satisfaction, home life or more time for recreation. An improved quality of rural life can contribute to a slowing down of the dramatic rural to urban exodus, as people try to escape the poverty and suffering of agricultural communities, only to find themselves in deeper poverty in town, sometimes turning to illegal ways of making ends meet.

A reduction in mechanical cultivation clearly has wider national and international benefits in reduced production of greenhouse gases, and also in slowing down soil erosion on sloping land, and moisture loss from soil surfaces (Bates, undated).

Not only do pesticides prevent losses on existing crops, but they broaden the range of viable crop options that a farmer can grow at particular times of year. For example, tomatoes can only be grown in the rainy season in Zimbabwe by using fungicide to prevent blight – without them, there is usually total crop failure. This rainy season production is also extremely lucrative; tomatoes have a highly elastic price response to demand, with rainy season prices being ten times dry season prices (pers. comm).

Figure 2 shows a simplified representation of the benefits relationships resulting from Pesticide Effect 1.

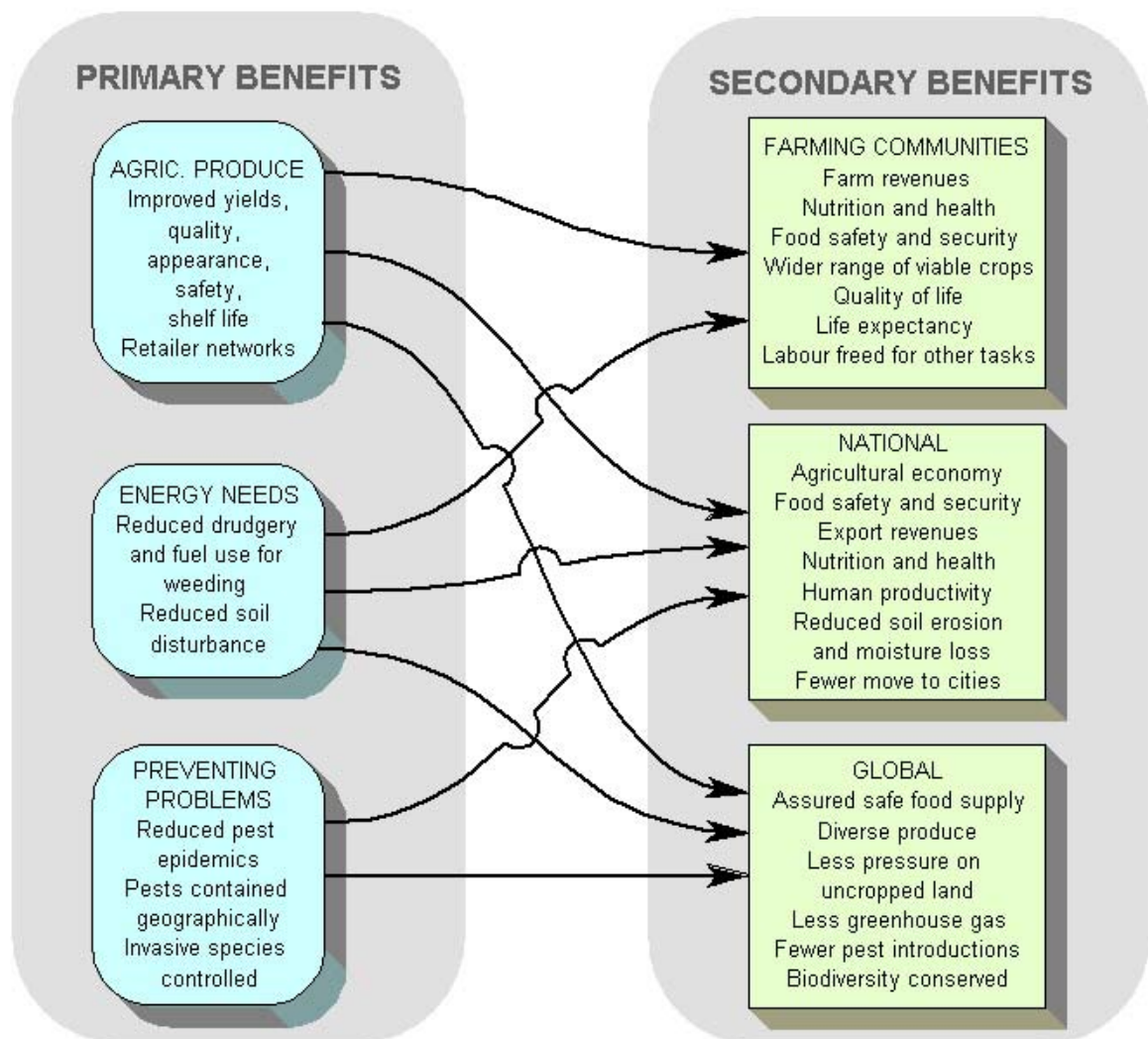


Figure 2. Benefits of Pesticide Effect 1. Using pesticides to control pests (including diseases and weeds) and vectors of plant diseases

Published evidence of benefits from Pesticide Effect 1.

Diet and Health

In the developed world we now recognise that the advantages from a diet containing fresh fruit and vegetables far outweigh potential risks from eating very low residues of pesticides in crops (Brown, 2004). Increasing evidence (Dietary Guidelines, 2005) shows that eating fruit and vegetables regularly reduces the risk of many cancers, high blood pressure, heart disease, diabetes, stroke, and other chronic diseases. The US National Cancer Institute's 5 A Day for Better Health Programme is a national initiative to increase consumption of fruits and vegetables. A similar

campaign exists in the UK (UK DOH, 2003) and many other countries, including Canada (Canada, undated) and South Africa (Health 24, undated). The Department of Health campaign in Britain is to “help reduce the risk of some cancers, heart disease and many other chronic conditions” which are the UK’s biggest killer diseases (5 a day, 2003). Not everyone has access to such health-promoting foods. Food and good nutrition can also delay the onset of AIDS-related illness and improve the quality of life for someone living with HIV and AIDS (World Food Programme, undated).

Gattuso (2000) wrote that banning some pesticides would reduce the availability, affordability and overall consumption of fruit and vegetables - a vital protection against cancer. Lewis *et al.* (2004, 2005) discussed the nutritional properties of apples and blueberries in the US diet and concluded that their high concentrations of antioxidants act as protectants against cancer, heart disease, and other chronic diseases associated with oxidative stress and aging. Lewis attributed doubling in wild blueberry production and subsequent increases in consumption chiefly to herbicide use that improved weed control. Gianessi (1999) largely attributed all year round availability of inexpensive and good quality fresh fruit and vegetables to the use of pesticides.

Improvement of agricultural yields and quality

Over the last 60 years, farmers and growers have changed the way they produce food in order to meet the expectations of consumers, supermarkets and governments. In doing so they have made many changes to the way they farm, including the extensive use of pesticides, in order to produce plentiful food, at a reasonable price, all year round.

Pesticides have had a key role in improving productivity to such an extent that India, a former country of famine has quadrupled grain production since 1951 (Dyanatha and Chand, 1999) and now not only feeds itself but exports produce (100m tonnes in 2003 - Indian export stats). Similarly outputs and productivity have increased dramatically in most countries, for example, wheat yields in the United Kingdom rose from 2.5 t/ha in 1948 to 7.5 t./ha in 1997 (Austin, 1998). Corn yields in the USA went from 30 bushels per acre to over a hundred per acre over the period from 1920 to 1980 (Purdue, 2006). Increases in productivity have been due to several factors including use of fertiliser, better varieties and use of machinery. However pesticides have been an integral part of the process by reducing losses from the weeds, diseases and pests that can markedly reduce the amount of harvestable produce. Demby’s review of data from 600 trials concluded that plant protection measures increased yield in cereals, rape, potato and sugar beet by up to 0.53 tonnes/ha in cereals and 0.44 tonnes/ha, 3.75 tonnes/ha and 3.6 tonnes/ha in winter rape, sugar beet and potatoes respectively.

Warren (1998) also drew attention to the spectacular increases in crop yields in the United States in the twentieth century, reporting that average US yields for 10-year periods during this century for 9 crops show that increases are from 2 to 7-fold, starting in the 1940s and had increased dramatically during the rest of the century. Webster *et al.* (1999) stated that "considerable economic losses" would be suffered without pesticide use and quantified the significant increases in yield and economic

margin that result from pesticide use. Webster and Bowles (1996) concluded that without pesticides, apple production would not be commercially viable and farmers would have to use their land for other purposes. In Russia, Petrusheva (1975) attributed orchard yield increases of 1.5 to 2 times to the use of pesticides. Damage done to fruits by the apple worm went down to 1-2%, and marketable percentage was 80-90% of produce. In the same country Zakharenko (1975), Keiserukhsky and Kashirsky (1975) and Chenkin (1975) all claimed that the profitability of the additional outlay on pesticides was repaid four to six times in increased production. Schmitz (2003) explored the potential effect on European crop productivity of possible EU legislation to reduce pesticide usage. He concluded that the evidence for the benefits of a reduction strategy were unconvincing and an imposed cut of 75% would reduce productivity to catastrophically low levels, that is, by between one third and two thirds of the original production levels.

Some countries officially recognise the beneficial role of pesticides. Seal and Baranowski (2000) reported that the Ukraine is planning to increase pesticide use due to crop losses in wheat and barley of over 25%, and over 30% in sugar beet and sunflower, a plan that is considered essential for continued transition to a free-market economy.

These increased yields bring important secondary effects of increased revenue and rural nutrition, along with a diminished pressure to cultivate uncropped land and wild areas that provide habitats for endangered species (WWF, undated) and attract national or international tourists. These benefits are increasingly significant and valued, sometimes by the same groups that express misgivings about the role of pesticides (Greenpeace, undated).

The following section deals with the benefits of some specific types of pesticide – in particular insecticides, herbicides and fungicides when used on a wide range of important crops that are grown throughout the world.

Insecticides in agriculture

The influence of insecticides on agriculture has been comprehensively reviewed by Staple (1979) and Finch (2000) states that they are best used as part of an integrated control strategy. Insecticides used to control insect pests that feed on crops or carry plant diseases prevent huge losses. Tatchell (1989) estimated that aphids and the virus diseases they spread would cause £120 million (c. \$200 million) in the UK without control measures being applied.

Many food crops benefit from the reduction of pests. Roubal *et al.* (2004) considered the effectiveness of various methods for controlling codling moth on apples and pears. Biological and cultural methods may be effective against moderate populations but they concluded that during epidemics, only preventative methods including the use of insecticides are effective. Masson *et al.* (2003) reported that combining insecticides with mating disruption could enhance the effectiveness of insecticides and reduce the need for 8-10 application/year down to two.

Finch and Collier (2000) recommended a similar combined approach to control insect pests on brassicas and carrots. While they encouraged the use of non-chemical methods, the authors recognized the vital role played by insecticides, concluding that the withdrawal of certain insecticides would leave farmers without any effective control measures and that carrot and brassica farming may prove unsustainable if insecticides were not used.

Chen *et al.* (2005) reviewed the establishment and spread of rice water weevil in mainland China's rice and discussed potential economic impacts of the insect as well as control strategies. They concluded that insecticides are, and will remain the primary control method to limit crop losses in infested areas and contain the insects' spread.

Insecticides can have other indirect benefits such as on international trade. Koppelberg and Cramer (1969) reviewed the significance of Mediterranean Fruit Flies as a quarantine pest and outlined the success of Spain's compulsory integrated insecticide treatment program for citrus. After the program's first year, export shipments rejected for fruit fly infestations dropped from 8.7 million kg (1-2% of exports) to 160,000 kg (0.2-0.5% of exports).

Comis (2001) reported that rootworms can cost US farmers \$1 bn in crop losses but baits have the potential to reduce pesticide use by half, and are environmentally friendly. Other such targeted techniques are seed treatment and trunk injection. Smith (2003) reported that corn seed treatment controlled rootworms well and controlled chinch bugs better than applying granular insecticide to soil. Seed treatment also saved time at sowing and reduced operator contact with pesticide. Tattar (2002) reported that microinjection of shade trees in the US with imidacloprid protected them against the newly introduced Asian Long-horned Beetle and used less pesticide than spraying. Tolman *et al.* (1986) reported that Canadian crop losses in a range of produce that included potato and onion were at least 60% without pest management chemicals, based on results from a series of detailed experiments.

Tropical conditions are particularly suitable for pests and diseases. Adipala (2000), in a detailed study of three pests of cowpea in Uganda i.e., flower thrips, the legume pod borer, and pod sucking bugs, reported on their economic importance. Thrips accounted for the greatest yield reduction (15.2%), aphids (10.4%), legume pod borers (15.2%) and pod sucking bugs (13.8%). Omongo (1998) also attributed low cowpea yields in Uganda to heavy biotic pressure, particularly by insect pests. His on-farm trials indicated that insecticide protection at all crop growth stages gave the best control, leading to yield gains of more than 50%. Egwuatu (1982) reported that in Nigeria, okra is attacked by a wide range of insect pests. In late season trials, the numbers of insects reached alarming proportions in all the plots within one week after planting, except in the insecticide (carbofuran) treated plots. Carbofuran protected the crop from planting to about 30 days after sowing with very small numbers of insects occurring during that period. He concluded that in Nigeria, insecticides appeared to be the only effective means of control.

Lee, *et al.* (1973) found that the maximum effect of disease and pest control in rice, as expressed by yield index of hulled rice, was 65%. The minimum effect was 30% and average effects were 42-45%. Caudwell (2000) concluded that an integrated pest management system (including insecticide) was necessary for Oil Palm in Papua New Guinea. Verghese *et al.* (2004) made an economic evaluation of the integrated management of the oriental fruit fly *Bactrocera dorsalis* in mango in India. An IPM package including three sprays of insecticide, 14 days apart, reduced fruit fly infestation by between 77 and 100% and cost benefit was positive except in years of very low infestation. Yadav and Chauhan (2000) evaluated insecticides against larval population of pod borer *Etiella zinckenella* on field pea in Haryana, India. Use of organophosphate insecticides controlled the pests effectively. Branch and Fletcher (2001) tried to grow peanuts without pesticides. Yields were low and the authors called for more resistant varieties to reduce production costs.

Moore (1983) reported that permethrin and fenvalerate can control leaf miner on tomato in Bolivia. Wilson and Otsuki (2004) explored food safety standards, using the banana crop as a model, and concluded that pesticides clearly have assisted in controlling pests and maintaining the availability of low cost and high quality food. They were of the opinion that international regulations need to be standardised because having different standards from country to country is confusing, costly and inhibits international trade. They claimed that developing countries suffer from increasing regulatory stringency and illustrated their point by stating that tighter restrictions on the pesticide chlorpyrifos had a two-fold effect in decreasing banana trade.

It is not only food crops that are threatened by pests. Wagner and Zhong (2004) reported on the long-term benefits to the growth of ponderosa pines from controlling south-western pine tip moth and weeds. Insecticide plus weeding produced the greatest tree growth and survival, and the lowest rate of tip damage.

Protecting food after harvest

Even after crops have been safely harvested, insecticides may be necessary. Dales and Golob (1997) reported that insecticides can protect stored grain in bags or bins from insect spoilage. Their trials in Tanzania showed that the larger grain borer *Prostephanus truncatus* and *Sitophilus* species can be controlled for at least nine months by applications of insecticide mixtures used in small quantities as protectants of shelled maize. Arthura *et al.* (2004) reported on susceptibility of stored-product beetles on wheat and maize treated with thiamethoxam. They concluded that the important pests of stored products (maize and wheat) can be successfully controlled by thiamethoxam. Even at 0.5 ppm, beetle mortality was significant, provided the exposure was continuous over several days. Zettler and Arthur (2000) reported on chemical control of stored product insects with fumigants and residual treatments and wrote that pesticides are often the cheapest and most efficient control strategy available. The authors use data from research studies with cyfluthrin, a pyrethroid insecticide used as a residual surface treatment, and data from developmental research with new fumigants. They concluded that chemical pesticides will have applications for controlling post harvest pests well into the 21st Century.

Fungicides in agriculture

Fungae are one of several causative agents of diseases of crops that can reduce yield and quality of food crops (Agrios, 2002) and they sometimes produce toxic compounds making the produce unfit to eat. The fungal pathogens that cause diseases adapt quickly so although plant breeders can sometimes incorporate resistance to a disease, this disease resistance often breaks down (Aubertot *et al.*, 2006).

Fungicides are extremely important in three ways. They reduce yield losses that are caused by disease, they improve the quality and appearance of harvested produce and they make some crops much safer to eat by reducing the natural toxins that fungi can produce. Ragsdale *et al.* (1991) wrote a detailed report on the benefits of fungicides in agriculture, citing many examples in which their use is essential for food safety. Minuto *et al.* (1997) speculated on the economic implications to the important sweet basil industry in Italy if disease control was compromised because chemicals registered for disease control on minor crops were becoming limited – presumably by new legislation.

Devastation by blight

Potatoes have been a historically important crop, sometimes devastated by disease before fungicides became available. During the summer of 1845, a "blight of unusual character" devastated Ireland's potato crop, the basic staple in the Irish diet. A few days after potatoes were dug from the ground, they began to turn into a slimy, decaying, blackish "mass of rotteness". Expert panels convened to investigate the blight's cause suggested that it was the result of "static electricity" or the smoke that billowed from railroad locomotives. In fact, the cause was a fungus that had travelled from Mexico to Ireland. Not until the invention in 1885 of an early pesticide, Bordeaux mixture, was there a way to protect crops from late blight, but by then up to a million people had died from starvation, and many more had emigrated.

The same disease, *Phytophthora infestans*, still threatens potato and tomato production today. In 1998 Cooke wrote that "without the use of fungicides, large-scale commercial potato production in Ireland would be impossible." The same applies elsewhere. Olanya *et al.* (2004) looked at fungicide use to protect potatoes grown in tropical highlands where late blight is the most significant constraint to potato production. They concluded that fungicides are vital to late blight control and potato production, being most effective and economical when their application is properly timed and their use is part of an integrated pest management strategy.

Bugiani and Ponti (1993) reported that late blight is the most important and feared tomato disease threatening production in northern Italy. Fungicides are essential there but a warning service for the occurrence of late blight based on climatic conditions had allowed growers to reduce sprays by 50% on average. Kassa *et al.* (2001) reported that late blight caused 100% crop loss on unimproved local potato cultivars in Ethiopia and farmers need to apply fungicides to control it in potato crops. The marginal rate of return of usage ranged from 104% to 487%. Tumwine *et al.*

(2002) compared different control methods to assess effectiveness of blight control in Uganda. Removal of diseased leaves reduced infection, but at the cost of reduced yield. Yield was highest by a significant degree with the fungicide treatments. Namanda *et al.* (2004) reported that six potato varieties all suffered from late blight in Uganda. Even a moderately resistant potato variety benefited by the application of mancozeb, and Kankwatsa *et al.* (2003) confirmed that potato growers in Uganda need to use Ridomil or mancozeb in areas of high rainfall. In India a closely related blight, *Phytophthora nicotianae*, affects bell pepper. Bhardwaj *et al.* (1985) reported that this disease discouraged farmers from extending cultivation of bell pepper, but that fungicides could successfully control the disease.

Protecting other crops from diseases

Fungicides now routinely protect many crops throughout the world. Doughty *et al.* (1998) concluded that fungal diseases of oilseed rape, a crop for which financial returns to the farmer are marginal in the UK, can have profound effects on the yield and crop physiology, and suggested that controlling diseases with fungicides will be important if growers are to provide processors consistently with seed of the required quality from crops. Fungicides are also important in reducing cereal diseases. Lescar (1981) pointed out that cereals are increasingly protected by fungicides in Europe. Lawrence and Appel (1997) reported that use of fungicides on cereals in Europe is now routine, and often two or three foliar applications are made to avoid losses that were only quantified after the 1960s. Cook and Jenkins (1998) discussed a series of fungicide efficacy experiments in wheat and barley grown in the UK that demonstrated consistent and significant production benefits from fungicide treatments. The authors calculated that the potential value of fungicides to UK cereal producers to be GBP 231 million.

Manktelow *et al.* (1996) concluded that in New Zealand apples, black spot (scab) and powdery mildew disease control currently depends on routine fungicide applications, although they estimated that there may be potential for about 25% use reduction before disease could reduce profit. Kolbe (1982) examined the effect of different crop protection programmes on apple yield and quality. He considered efficient control of diseases and pests to be essential for optimizing yield and quality. In plots that received no crop protection treatments at all, the yield was reduced by 43% in comparison with those given routine treatments for the control of fungal diseases and insect pests. This yield reduction was accounted for mainly by a 47% reduction in the number of apples produced per tree. Fruit quality was also substantially lowered. Cuthbertson and Murchie (2003) reported that apple scab is the most serious disease in Northern Ireland Bramley orchards and that protectant and eradicant fungicide sprays from bud burst onwards are essential to prevent infections. They concluded that it is not economically feasible to produce Bramley's Seedling apples in Northern Ireland without the aid of a fungicide programme.

Babu *et al.* (1995) reported that in Malawi, when early leaf spot on groundnut was not controlled, yields were reduced (depending on area cultivated) by an amount that could have supported an additional 1.75 to 14.0 persons per family. Smith *et al.* (2000) reported that peanut yields were 36% higher when fungicidal seed treatments were used while only adding 4% to production costs. Grichar *et al.* agreed, concluding that peanut losses from diseases are 5% with fungicides but would be

50% without them. Weaver reported (1998) that pecan scab caused by *Cladesporium cayigenum* cost Californian growers \$22m. Fungicides applied by air blast sprayers control the problem and yields have quadrupled.

Davis *et al.* (2000) estimated that without fungicides, carrot losses would be an estimated 24%. Using pesticides enabled a farm to produce a record 22 tons per acre. Pande (2005) reported that the area under chickpea production in Nepal had dropped from 54,000 ha in 1981-82 to only 19,000 ha in 1997-98, mainly due to its susceptibility to *Botrytis* grey mould. An epidemic of this disease in 1997-98 had a devastating impact and virtually eliminated chickpea production from the country. Since then, because varieties with *Botrytis* grey mould resistance are not available, disease management in Nepal has relied on fungicides.

Priestley (1981) observed that winter wheat, protected by fungicide against mildew and other diseases, stayed green longer because the disease control delayed senescence and this improves performance and yield. Penrose (1998) drew attention to the importance of disease control in stone fruits in Australia where pre-harvest attack by leaf curl, scab and canker and rust and post harvest rots such as brown rot need to be controlled using fungicides. Ploetz (2000) reported that fungicides are needed to control Black Sigatoka in bananas.

Englert and Maixner (1992) reviewed two fungal diseases of grapes that were introduced to Europe in the middle of the 20th century, i.e., powdery mildew and downy mildew, which on arrival from North America caused catastrophic losses. They wrote that chemical control of grapevine diseases dates back as far as 1848, when for the first time sulphur was used against powdery mildew, and that copper compounds have remained in use since 1885. Effective control of all major fungus diseases with the exception of powdery mildew became possible with the introduction of synthetic organic fungicides in 1950 and the instigation of regular spraying programs that in Europe vary from 5-7 applications in the northern regions to 10-12 in the south. They concluded that protection of grapevines from losses through downy and powdery mildews and *Botrytis* seems impossible in the immediate future without recourse to chemical fungicides. Bulit and Lafon (1978) and Spencer (1981) similarly synthesised the history of vine diseases, reporting that sulphur has been in use for almost 150 years in France and is still effective in controlling powdery mildew.

Brunelli, *et al.* (1996) examined the efficacy of a number of fungicides, in controlling powdery mildew in grapes and found that fungicides can be very effective at protecting grape quality if they are used as a preventative treatment or immediately after the first symptoms appear. Powdery mildew can impact on wine quality (Anon, 2004) and even slight grape infection leads to compositional changes via factors such as delayed ripening, increased acidity, and reduced colour and phenolics in red varieties. Berry and bunch weights are severely reduced in diseased grapes, possibly due to desiccation of infected berries. Importantly, taste and character are affected unless the disease is controlled.

Hops too are affected by powdery mildew. Royle reported in 1978 that it is the oldest known fungal disease of the cultivated hop. Originally known as "fen", it has been

the most serious hazard to hop growers in the east-and mid-Kent areas of England since at least 1700. The disease remains troublesome causing some crop failures though in general it is kept under control through frequent fungicide applications. Downy mildew became serious for the first time in West Germany in 1972, since when it has required annual systematic control measures. As on grape vines, sulphur has been the mainstay of control since early times and is applied to 90% of the area of hop cultivation. As long ago as 1920, Salmon had reported that owing to downy mildew, hops cannot be grown in Germany without a considerable number of applications of Bordeaux mixture each season.

Penrose (1998) looked at disease control in stone fruits in Australia, where during blossoming, from 1-3 fungicide applications are made at monthly intervals to control the blossom phase of brown rot, then during the summer, further fungicide applications are made at about monthly intervals to control rust and scab. He concluded that it was difficult to see where reductions can be made in the fungicide program for stone fruits in wet seasons and in areas that experience high summer rainfall and warm temperatures.

On olives, Shabi *et al.* (1994) reported on a series of experiments and concluded that leaf spot in Israel could be controlled using various fungicides to protect against fall infections. Michelakis (1990), Stylianos (1990) described the damage various insect and fungal pests cause to olives, with specific attention to yield and fruit quality impacts. Protecting olives from such damage is vital in increasingly competitive markets, especially markets for edible oils. Graniti (1993) reviewed olive scab disease in 1993, which is widespread in the Mediterranean region, causing losses mostly from defoliation of severely infected trees, with consequently reduced yield. Chemical control schedules include the application of preventative treatments before or at the beginning of the main infection seasons using Bordeaux mixture, copper oxychlorides or some persistent preventive fungicides such as dodine or chlorothalonil.

Hohnson *et al.* (1962) concluded that soil fumigation was essential for maximum strawberry yields in southern California, with growth response and high yields following soil fumigation being attributed primarily to the control of injurious root-infecting fungi. Improved varieties with potentially higher yields than existing types can be particularly susceptible to diseases. Wander *et al.* (2004) reported that grey mould, *Botrytis Cinerea*, is a serious problem in strawberry all over the world, necessitating sprays up to every 5-7 days during flowering and harvest. Their weather-based model used in decisions on spraying led to a slightly lower input of fungicides and a slightly higher percentage fruit rot in comparison with a routine spray schedule.

Coffey (1990) reported that the promise of early and high coconut production from new dwarf hybrids offered a potentially attractive possibility for raising the living standards of smallholder farmers in Indonesia during the 1980s. Unfortunately, the outbreak of bud rot and premature nut fall disease in some coconut gardens resulted in some serious losses in production and an erosion of confidence in the hybrid program. Measures aimed at containing further outbreaks included the use of protectant fungicides during the rainy season.

Byford (1996) surveyed foliar diseases on sugar beet in 18 countries and the control measures used against them. Damage from *Cercospora beticola* alone can cause yield losses in some countries that, in the absence of treatment, range from 25-50% and average over 10%. Ayala and Bermejo (2003) reported that one third of global sugar beet cultivation, then estimated to be 2,400,000 ha in 33 countries, suffers from moderate to high severity attacks of the disease, causing production losses over 10% and requiring more than one fungicide application. They considered that fungicide treatments to control *Cercospora* are essential to maintain current levels of yield.

Avoiding production of poisons by crops and their diseases

When stressed or attacked by diseases, many plants or the pathogenic organisms causing the diseases produce chemicals that are acutely toxic. An extreme example is the cereal disease ergot (*Claviceps purpurea*) that produces highly toxic and sometimes lethal alkaloids in the grain under certain conditions unless protected by a fungicide. Kvien *et al.* (1993) speculated that projected restrictions on use of pesticides on peanuts would reduce returns by \$500 to \$1000 and increase presence of carcinogens.

One family of mycotoxins, the aflatoxins, are potently carcinogenic and immunotoxic and can cause growth retardation in animals. Aflatoxin and fumonism (a toxin associated with *Fusarium*, that causes brain and kidney damage) can affect both humans and animals. It does so via infestation of maize grain either in the field or in storage according to Bruns and Arnold (2003). These authors reported that stress increases infection, so production practices that produce high yields are basically the same ones that help control mycotoxins. Evidence of acute aflatoxicosis in humans has been reported from many parts of the world, especially in developing countries (WHO, 2005). Aside from the acute effects of aflatoxin poisoning, there is particular concern about the long-term effect of exposure to low levels of aflatoxins. Epidemiological studies have shown a strong positive correlation between aflatoxin levels in the diet and primary hepatocellular carcinoma in the People's Republic of China, Kenya, Mozambique, the Philippines, Swaziland, Thailand and Transkei of South Africa and estimates are around 12-13 cases per 100,000 annually. The synergy between exposure to aflatoxins and infections with hepatitis B increases the risk of hepatocellular carcinoma substantially to 59.4 in Africa. Gong *et al.* (2002) reported that many people in developing countries are not only malnourished but also chronically exposed to high levels of toxic fungal metabolites (i.e., mycotoxins).

Etcheverry *et al.* (1987) studied the influence of ten commercial fungicides and insecticides on growth and formation of aflatoxin B1 by *Aspergillus parasiticus*. Four of the five fungicides investigated in concentrations corresponding to commercial practice inhibited growth and toxin production in the laboratory media. Even in the fifth case, aflatoxin B1 could not be detected although the *Aspergillus* continued to grow. Among the five insecticides investigated, one inhibited toxin formation but not growth and one inhibited growth as well as toxin formation. These results demonstrate that pesticides can reduce production of toxins directly or indirectly

although inhibition was much less after prolonged incubation of sterile seeds inoculated with *A. parasiticus* spores.

Abert *et al.* (2002) discussed the implication in wines of phenolics and other chemicals that plants produce to defend themselves from diseases. Use of fungicides on vines reduced production of toxins with the beneficial side effect of boosting production of compounds known to enhance antioxidant activity and to reduce thromboses in consumers.

Gray and Hammitt (2000) projected the likely effects of banning organophosphates and carbamates, giving examples of the substituted risks and how they could be manifested. They referred to the NRC report in 1996 that said that natural carcinogens in plants are at higher levels than artificial ones (i.e., pesticides).

Herbicides in agriculture

Herbicides, i.e., chemical substances used to kill or control unwanted vegetation, are the most widely used type of pesticide and comprise around 50% of all crop protection chemicals used throughout the world, compared with insecticides and fungicides that are around 17% each (CropLife, 2004). Using herbicides to reduce the drudgery of persistent weeding makes sense, especially in cases of chronic labour shortages. This does not necessarily lead to 'dependency' but can in many cases be classed as successful adoption of a cost-effective technology.

Weed competition is the major constraint that limits yield in many crops. Without herbicides there would be estimated US \$13.3 billion loss in farm income in the US (Anon, 2003). Yancy (2005) put the figure higher for benefits of herbicide use at \$21 billion annually, against a cost of \$6.6 billion for the product and application, thereby reducing losses to weeds by 23% and reducing loss of farm income valued at \$8 billion. Bridges (1992) reported that US losses due to weeds of \$4 billion would be \$20 without use of herbicides. Miller (1982) analyzed the primary and secondary productivity and labour impacts of improved weed control, as achieved with herbicides, on farmers and rural communities. He concluded that increased agricultural productivity creates direct economic benefits for farm families in terms of increased income, which in turn propagate throughout rural communities creating secondary benefits of rural development and stimulated regional economies.

Herbicides also reduce seasonal variation in labour markets and the total labour needed for hand weeding, stabilizing labour requirements and freeing workers to pursue higher-value opportunities.

Scragg (1964) reported that potato had sometimes shown marked increases in yield associated with chemical weed control, even when the degree of weed control was about the same as that obtained by several mechanical cultivations. He proposed that the reason was to be found in the damage and check to growth associated with cultivation, and called for immediate adoption of the chemical techniques for weed control with first and second early crops. On stony soils where breakage and wear of implements is a serious problem, chemical weed control has an obvious additional appeal.

Bigler *et al.* (1992) reported that weed control in cereals is accomplished almost exclusively by herbicides in Europe, where 11% of the world cereal production is grown on only 6% of the world's cereal acreage, indicating highly intensive production. Griffiths (1972) reported that cereal herbicides accounted for 50% of farmer expenditure on pesticides, with UK farmers spending more than £8 million on weed control in cereals in the season 1971-72. He reported that the standard rotation would be impossible in many parts of the country without herbicides for the control of wild oats and blackgrass. He pointed out that the benefits of rotation – reduced threat from soil-borne diseases, nematodes and insects and improved soil fertility management – are well known but that herbicides “provide the intensive cereal grower with the means of remaining in business”.

Bernard and Rameil (2005) pointed out that in recent years the quantities of cereal herbicide active ingredient used on French cereals had fallen as a result of innovation, new substances which are effective in small doses, reduced doses of old substances (improved formulations, purification of active isomers) and development of post-emergence products that make it possible to carry out integrated weed control adapted to the floral species present. Faivre-Dupaigre and Rognon (1964) estimated that the average increase in yield obtained as a result of weed control was a 13% increase over unsprayed plots. Svensson (1982) reporting on cereals in Sweden found that no other control methods can compete with chemical control against certain annual weeds, hence more than 80% of the total area of cereals is treated with herbicides. He reasoned that without herbicides, a radical reduction of the area of winter cereals would be necessary in areas where key annual weeds are common. Balsari (1993) compared mechanical weed control with herbicides in the Netherlands on maize and soyabeans over several years. In maize mechanical weed control was 25% to 44% less effective than that obtained with herbicides and gave a yield reduction from 6% to 18%. Presence of weeds in oilseed rape has an additional deleterious effect, according to Lutman (1989) who reported that herbicides are needed in the UK because if weed seed contamination exceeds 2%, the crop is rejected by the crushers.

Schroder (1984) reported that increased use of herbicides accounted for 20% of the increase in corn yields during the period 1964-1979 in the USA. In soybean, mechanical intervention showed, in comparison to herbicides, an average of 55% poorer weed control and 45% less yield. Ebner (1982) concluded that herbicides have definite benefits to tropical farmers and should be adopted as part of an integrated approach to realize maximum benefits. A report by Winrock International (2002) reported that weeds and poor soil fertility are big constraints for African smallholders. Kibata (2002) reported that herbicides used in two crops in Kenya improved the economic yield and help in particular when labour is short for weeding at critical times. Yields increased dramatically (94% in beans and 53% in maize) when herbicides were applied.

Armitage (1976) and Zhang (2003) reported that weeds in China cause losses of millions of tonnes, with herbicides being used on half the area and considered very effective. Prematilake *et al.* (2004) reported that in Sri Lanka weed control with herbicides was superior to that of hand weeding. Even sugar cane, a good

competitive crop in terms of weed suppression when it has become established, is severely affected by competition from weeds in the early stages of its growth and the weeds have to be controlled during this critical period of up to 40 to 60 days from planting to prevent yield reductions of up to 35% (Nene, 1987). Timely weed control was found to be essential for better crop establishment, tillering, vigorous growth, higher fertilizer efficiency and increased yield. Manual weed control was less efficient and its cost was ever increasing. Ibrahim (1982) had come to similar conclusions in Sudanese sugar.

Rice too suffers from weeds. Singh (2002), reporting on what is the predominant crop of India, contributing 45% of the total food grain production, asserted that weeds are the major constraints in medium land rice even under puddled conditions. The rising labour cost and lack of available labour during the critical period warranted an effective and economic weed control practice to prevent a reduction in rice yield due to weeds that ranged from 28 to 48% based on comparisons that included control (weedy) plots. Naylor (1992) explored the implications of pre-emergence herbicide adoption in Javanese rice production considering herbicides to be: "As revolutionary as the sickle or small rice mill, this technology reduces the labour required to produce rice by nearly 75% and cuts production labour costs by approx. 60%".

Chikoye *et al.* (2005) reported that the average grain yield on farmers' fields is still very low in Africa. Among other factors, a significant portion of the yield gap is attributable to poor crop management, notably inadequate weed control. In West Africa, he attributes maize yield losses ranging from 50% to 90% to weed competition. Manual weeding is the predominant method of control used by smallholder farms in Africa. However, this method is time-consuming, laborious, and very expensive, whereas herbicides were shown to improve yield.

Nagda *et al.* (1991) reported that on Indian Pearl millet, atrazine and some hand weeding gave the best seed yield and income. Koch (1992) estimated that the amount of food lost through weed competition, despite weed control, was 25% of potential production in developing countries, and was one of the major labour-consuming operations in traditional crop production, amounting to 30 - 70% of the total labour input. Yallew (1995) reported that Ethiopian wheat production in marginal areas responded well (profitably and effectively) to herbicide use.

Nadanassababady reported in the Indian Journal of Weed Science in 2002 that weed competition is one of the important biological constraints in cotton cultivation. Highest seed cotton yield was obtained from a weed free treatment of four weedings, or use of a herbicide treatment. Yadav *et al.* reported in 2003 that losses caused by weeds in cotton ranged from 40-75% depending upon the nature and intensity of weeds. Traditional methods of hand weeding and hoeing, in addition to being expensive and time consuming were ineffective in controlling the weeds as new weed seeds germinated after every hoeing and re-infested the crop. Moreover, hoeing is not possible during the rainy season and labour shortage at that time further accentuates the problem. Under these situations, chemical and/or integrated methods of weed management are the only viable and feasible alternative. They

reported that usage of pre-emergence herbicide proved best, reducing the dry weight of weeds by 80 to 88%.

Also in India, Behera *et al.* (1999) said that weeds reduce yield of dry land crops by 37-79% and the traditional practice of manual weeding has become costly and cumbersome and is anyway, less effective. Porwal (2002) summed up with the comments that severe infestation of weeds particularly in early stage of crop establishment ultimately accounts for a yield reduction of 40% and that farmers' practice of manual hoeing is costly, time consuming and back breaking, particularly in heavy soils, whereas herbicides provided an economic and labour benefit.

Rameshwar (2002) reported on work with onions where weeds interfere with development and growth of the onion bulb thereby reducing bulb yield by 40-80%. Removing the weeds manually throughout the crop season may not be feasible or economical. The highest marginal benefit versus cost ratio of 53 was with the application of an herbicide. The lowest marginal benefit versus cost ratio of 7 was recorded with farmers' practice of hand weeding.

Kurmawanshi (1995) reported that soya bean suffers from severe infestation of a large number of weeds that reduces the yields to the extent of 18.83 to 42.37%. He noted that hand weeding and inter-cropping are the traditional methods of weed control but are now costly, time consuming, and cumbersome particularly in heavy soils. Herbicidal treatments performed equally well as three hand weedings in terms of weed intensity, weed biomass, and seed yield but use of the herbicide proved to be more economically viable with regard to cost-benefit ratio. Itnal *et al.* (1993) found that weed infestation was one of the major constraints limiting the production of irrigated groundnut in India. When labour was not available or prohibitively expensive it was extremely difficult to maintain crops free from weeds in the initial stages of growth. Herbicides did the job and increased yields.

Zanin *et al.* (1992) calculated the cost-benefit thresholds for chemical weed control in North-Central Italy and herbicide use always had a probability of positive net return of >80% for wheat, maize, and soybeans and >95% for sugar beets.

Hartley and Atkinson (1972) pointed out an animal welfare benefit from using herbicide in New Zealand. Three herbicides were assessed for barley grass control in animal pastures. All chemical treatments reduced the barley grass content of the sward by over 95% and substantially increased lamb growth rates over the summer in spite of a reduction in dry matter. The growth rate of lambs grazing the barley grass infested control paddocks was severely checked from January through to March and this was associated with a high level of eye damage.

Roques (1976) reported that herbicides helped to reduce frost damage and prevent soil erosion on grapes in France (using no tillage systems) as well as avoidance of mechanical damage and reduction of costs. Decion (2000) reported that the use of pre-emergence herbicides has been shown to be an essential technique in the vast majority of wine-producing areas.

Difficult or dangerous weeds

Control of noxious, difficult and parasitic weeds are special examples in which herbicides can have an important role. Geoffrion (2000) discussed the importance of weed control when toxic plants are present, particularly roots of weeds such as briony and arum that enter plots from field edges. Unless controlled, these poisonous plants can be confused with edible carrots, potato or horseradish and the author cited a recent case of such poisoning.

Yoldwasser *et al.* (2003) found in a study in Israel that efficient, selective, low cost and easy to apply herbicides can be used for control of the parasitic weed *Orobanche*. Haidar Sidahmed *et al.* (2005) too reported that herbicides can be used to manage the parasitic weed *Orobanche ramosa* (Branched Broomrape) on potato and other crops. Low doses of glyphosate controlled the weed without damaging the crop. Chikoye *et al.* (2002) reported that spear grass is a noxious weed widespread in most tropical zones of the world. Their studies in West Africa in maize and cassava to examine different tactics for control showed that plots that received glyphosate or those weeded five times had 28–59% higher crop yields than plots weeded twice at all locations. It was cheaper to use glyphosate than hand weeding for spear grass control in both crops. Puricell (2005) discussed control of *Anoda cristata*, a problem weed in soyabean production that can reduce yields significantly. In systems of use reduced tillage the soil seed bank of the weed increased but using glyphosate, even at half dose rate, reduced the numbers of weeds and seeds considerably and gave 100% control at the full dose. Darkwa *et al.* (2001) worked with two grass weeds, *Cyperus rotundus*. and *Imperata cylindrica* that prevent potential maize yields being reached in Ghana. Trials showed that tuber populations of *C. rotundus* could be reduced by 95% after glyphosate application at 1.8 kg a.i./ha. Atrazine and some hand weeding gave the best seed yield and income in India.

As reported above, Lutman (1989) reported that herbicides are needed to suppress weeds in oilseed rape because if weed seed contamination exceeds 2%, the crop is rejected by the crushers.

Removing weed competition in tree crops

Trees too benefit from removal of weed competition, particularly during the establishment period after planting. Groninger *et al.* (2004) reported that early growth of ash trees can be limited by competition from weeds. Applying pre-emergence herbicide sulfometuron, and post-emergence glyphosate, increased tree height and diameter, whereas tillage produced no response. Kuan *et al.* (1991) discussed the importance of weed control in Malaysian rubber, palm and cocoa plantations and concluded that herbicides were an important part of successful integrated weed management.

Saavedra and Pastor (1996) quantified the extent of weed infestations and noted that the use of residual herbicides in olives increases crop yield, reduces costs, and soil erosion. Torrisi (1969) outlined the yield and quality benefits of herbicide adoption in Sicilian citrus production. He particularly emphasized their role in no-till production systems. In coconuts Senarathne *et al.* (2003) reported that in Sri Lanka, coconut yield was increased significantly when glyphosate was applied to treat

weeds. Even at a reduced rate (1.44 kg a.i. ha) there was a 25% increase in nut yield over the uncontrolled weed plots and this rate was found to be the most effective and economical method of controlling weeds in plantations. Glaze (1975) considered that use of herbicide in cucurbits was essential because the crop can be damaged by mechanical weed control.

Pesticides that reduce labour, energy and water requirements

Removing weeds manually is very labour-intensive (Riches, 2005) and therefore expensive. Using herbicides to reduce the drudgery of persistent weeding, makes a lot of sense, especially in cases of chronic labour shortages. HIV AIDS has exacerbated the labour shortages in affected countries (FAO undated). In Ethiopia, a study found that AIDS-afflicted households spent 50-66 percent less time on agriculture than households that were not afflicted. In Tanzania, researchers found that women spent 60 percent less time on agricultural activities because their husbands were ill. By one estimate approximately 2 person-years of labour are lost by the time one person dies of AIDS, due to their weakening and the time others spend providing care. Tending for the sick takes a considerable amount of time, which is no longer available for agriculture, and the sickness and death of an adult results in the inability of the household to cultivate all the land at its disposal.

Takehita *et al.* (2001) reported that farmers in Japan used to spend 50 hours to weed 0.1 ha by hand. In reality, a farmer used to spend 6-7 days per 0.1 ha for weed control (before herbicides). The same problems with manual weeding apply elsewhere. An estimated 70 million additional workers would be required in the US alone if hand-weeding was the only option (Anon, 2003). Also weeding is not a popular job so people are not always willing to do it. Mechanical weeding is difficult in many crops and in some parts of the world neither the motive power nor the machinery is available. Herbicides overcome many of these problems because they control weeds in a way that is quicker and easier than mechanical methods and usually requires far less manpower.

Chemical weed-killers sometimes provide additional benefits such as better control of certain problem weeds. Sperlingsson (1982) concluded that it would probably be very difficult to conduct profitable sugar beet production in Sweden without herbicides. The economic yield would be reduced and it would be very difficult to find the estimated 13000 workers to do the exacting, monotonous work that would be needed.

Lum *et al.* (2005) reported that Cogon grass, an aggressive perennial weed, causes severe yield losses up to 50% in major crops of the moist savannah of West Africa. Management options commonly used by small farmers to control Cogon grass are slashing, hand-weeding, burning, deep tillage, use of cover crops, and herbicides. Hand-weeding and hoe-tillage are very popular but use up lots of labour and are not effective on underground rhizomes. Nicosulfuron increased corn grain yield at Alabata by 96% in 2000 and 100% in 2001.

Herbicides reduce the need to disturb the soil. Some environmental production systems in which ploughing is not practised (seeds are drilled directly into stubble from old crops) would be impossible without herbicides. These no till, zero cultivation or stale seedbed techniques remove the need for cultivations that would cause an estimated 150 million tonne increase in soil erosion per year. (Anon, 2003). (CropLife, 2004a) reported that in Australia, many soils in areas dominated by wheat-pasture rotations have low moisture holding capacity, are nutrient-poor, and are prone to wind erosion. Accordingly, the main focus of conservation tillage technologies in wheat cultivation, which have now been adopted over large areas, has been to conserve moisture and reduce soil erosion. CropLife (2004b) also reported that no-till systems involving herbicides increased maize yields by 45% in a normal year in Uganda, and by 48% in a dry year. It was also reported that direct seeding of pre-germinated rice – leading to water savings of 15-20% - has been facilitated by the use of herbicides to control the difficult weed, red rice.

Pastor and Castro (1995) reviewed a series of trials in which olives were grown with either mechanical or chemical weed control. Chemical weed control reduced soil erosion by 400% (40 tonnes/ha) and provided an average production increase of 16% due to increased soil moisture and reduced root damage compared with tilled systems.

Semb Torrensen (2003) reported that a combination of glyphosate and post-emergence herbicide was necessary to control different biological groups of weeds in a reduced tillage system in Norway. All weed control practices (including herbicides especially) return a high energy output in relation to the input because of the tremendous increase in crop yields when weeds are controlled (Nalewaja, 1975).

Chikoye (2004) reported that weeds and shortage of labour for their removal are two of the most important production constraints in smallholder farms and smallholder farmers spend 50-70% of their total available farm labour on weed control by hoe-weeding maize. Herbicides were shown to be effective in trials but are said to have much more potential for increased use by farmers. The heavy labour demand of weeding in maize was emphasised by Parker (1982) frequently contributing to a labour bottleneck early in the rainy season when other crops are also being planted and weeded. Delaying weeding to spread the labour loads led to yield losses, while delaying some of the planting also reduced the potential yield of the crop. In replicated trials in the first season, herbicide use gave an 11% yield advantage over traditional cultivation and saved 16 man-hours/ha or 80% of the labour normally used for weeding. Jennings *et al.* (1979) stated that crops that have high labour requirements for weeding were becoming more difficult to grow unless herbicide was used. They found that economic returns from herbicide use were very positive too.

Aliyu and Lagoke (2001) reported on ginger production. Weed control with herbicides was more profitable because although the yields were comparable with hand weeding, the cost of labour was more than that of using herbicide. Clark *et al.* (1998) looked at tomato and corn production in California and concluded that on both crops, weed damage was more of a problem than losses from pests and diseases. In corn, pesticide use could be reduced by 50% or more with little or no yield reduction whereas on tomatoes pesticide reductions would be costly due to the

dependence on hand hoeing as a substitution for herbicides. In tomato, reducing pesticide use by 50% would increase pest management costs by 50%.

Organic alternative?

Suspicion about chemicals in food is fuelling sales of organic crops (MAF, 2006) but it is by no means certain whether organic production could sustain the world's growing population (Oerke, 2004).

Moreover the financial viability of crops grown without any chemicals may be less attractive as their supply increases and the price differential between organic and conventionally grown crops is reduced. Peacock and Norton (1990) reported that organic growers lose an unacceptably high and unaffordable proportion of their revenue to pests, and many growers of organic crops rely on the market price premium to counteract the reduced yields (Moore, 2006). Olsson and Nordstrom pointed out in 2002 that Swedish sugar beet yields in organic growing are substantially lower than in conventional beet growing, although it is unclear what proportion of this loss is attributable to poorer soil fertility. The average yield in organic sugar beet production during 1994-1999 varied between 60-78% with an average of 71% of the yield level in conventional beet growing. Yield levels in 2000 and 2001 reached around 7 tons of white sugar/ ha corresponding to only 87% of the yield level in conventional growing in 2001 due to poor weed control, later drilling and poor plant establishment.

A comment on the BBC website (2006) was that organic production is slower, more labour intensive and generally has lower yields than conventional methods and is usually more costly and therefore not always affordable. Evidence of the latter point is that organic carrots and broccoli in the US can sell for almost double those from conventional farms (USDA, 2005). A United States Department of Agriculture report (2004) highlighted the reduction in organic kiwifruit acreage in response to elimination of price premiums for organically produced fruit and concluded that production without pesticides is not economically viable without significant price premiums.

Webster *et al.* (1999) explored the theoretical economic implications of three pesticide regimes on wheat in UK. Without pesticides the profitability fell by £130 per hectare (over 20%) and yield by a much greater percentage (over 30%). They suggested that if the area of organic wheat increased, the reduced yields would need to be made up by importing grain.

Trewavas (2004) refuted many of the ideologically based claims about the superiority of organic production practices and food. He specifically refuted assertions made regarding pesticide use and residues and their relationships to acute and chronic diseases, soil fertility, air and water quality, biodiversity, farm sustainability, and energy use. Nickolson and Hirsch (1998) reported that long-term exposure to pesticides over 20 years had no detrimental effect on the soil micro-organisms.

It is worth noting that pest resistant crop varieties usually derive their resistance from the production of naturally occurring pesticides within the plant – hence the

withdrawal of a new variety of insect resistant potato due to its high solanine content (Jadhav *et al.*, 1981)

Kvien (1993) proposed that organic peanuts would require much higher labour cost and to justify these increases the price would need to be 1.95 that of the conventionally farmed crops. Elliot and Mumford (2002) questioned the logic of organic apple production that relies on price premiums in a niche market and prescribes certain technologies on ideological rather than pragmatic grounds. They suggest that greater overall benefits can be achieved by the use of legislation to restrict the more harmful technologies, so shifting the entire industry into integrated production.

Weibel *et al.* (2004) concluded that the yield risk in organic fruit growing is considerably higher than in integrated fruit production and goes along with average yield decreases of 15-30% in organic systems. Groot (2000) reported that fruit trees given the organic treatment in a three-treatment comparison trial in the UK had to be grubbed out after seven years because the organically treated trees had fruit tree canker.

Oerke *et al.* (2004) examined the role of pest management in meeting rapidly increasing global food needs and concluded that "pesticide-free [food] production would be a disaster". Saba (2003) reported that even high consumers of organic products agreed that "without the use of pesticides more human beings would suffer from hunger".

PESTICIDE EFFECT 2. CONTROLLING HUMAN AND LIVESTOCK DISEASE VECTORS AND NUISANCE ORGANISMS

Context

In warmer climates especially, insects can spread killer human diseases such as malaria, sleeping sickness, river blindness and a range of serious fevers and disfiguring or debilitating illnesses unless they are controlled. It is difficult to imagine or convey the despair and frustration of parents being unable to save their children from malaria, or of villagers who cannot tend their crops because of blindness. Gratz (1994) asserted that vector-borne diseases are most effectively tackled by killing the vector. Insecticides are often the only practical way to do this but are being under-exploited (Townson, 2005). WHO (2004) claims that without access to chemical control methods, life will continue to be unacceptably dangerous for a large proportion of mankind.

Overview of primary and secondary benefits

The most obvious benefit of controlling a wide range of human and livestock disease vectors is the lives saved that would otherwise have been lost. With regard to livestock, this translates to secondary benefits of additional livestock revenue and

reduced veterinary and medicine costs. The higher yields and quality provide a boost to the national economy and may allow access to export markets, generating valuable foreign exchange. There will also be less likelihood of international spread of disease.

In the case of humans, the increase in life expectancy leads to a happier society, more confident in its future. Most fatalities from malaria are in young children and pregnant women. A reduction in infant mortality is usually correlated with a decrease in family size – people have fewer children if they think they are more likely to survive. Children in these smaller families are better cared for and have better life quality. Ensuring the survival of pregnant women ensures there is a carer for her other children and has a similar effect on the well-being of communities.

However, there are also substantial benefits to reducing the number of people suffering sub-lethal effects of vector-borne diseases. The suffering endured by bouts of malaria or the insidious effects of onchocerciasis on eyesight – river blindness – has a debilitating effect on the morale and productivity of communities, not to mention the cash cost of medicines to treat these diseases.

Of less obvious, but no less significant benefit is the prevention of misery and disturbance caused by various biting insects, whether they transmit disease or not. These include mosquitoes, blackflies, midges, other biting flies, fleas and bedbugs. Studies in Cameroon have found people in some areas being bitten up to 2000 times per day by *Simuliid* blackflies. This effectively prevents them doing any useful agricultural or other work due to the nuisance and constant irritation. One long term effect of these bites is depigmentation of the skin, causing social problems and inability to find life partners. The whining noise of mosquitoes flying – especially *Culex* species - can also prevent people sleeping.

Insects such as cockroaches and houseflies are mechanical vectors for various organisms that cause diarrhoeal diseases, which are rated by UNICEF as the number one killer of children under five. When serious vectors and nuisance insects are controlled, previously uninhabitable areas become habitable and quality of life increases in both rural and urban environments.

The impact of biting flies is not confined to the developing world – America, Canada and many other countries use a lot of pesticide to control mosquitoes, blackflies and other insects so that people can live more comfortably and enjoy their recreation undisturbed. If such insects were not controlled, there would be a severe impact on tourism levels and revenue. Recent arbovirus incidents in the USA have drawn attention to the potential for biting insects to transmit serious diseases even in the developed world.

Figure 3 shows a simplified representation of the benefits relationships resulting from Pesticide Effect 2.

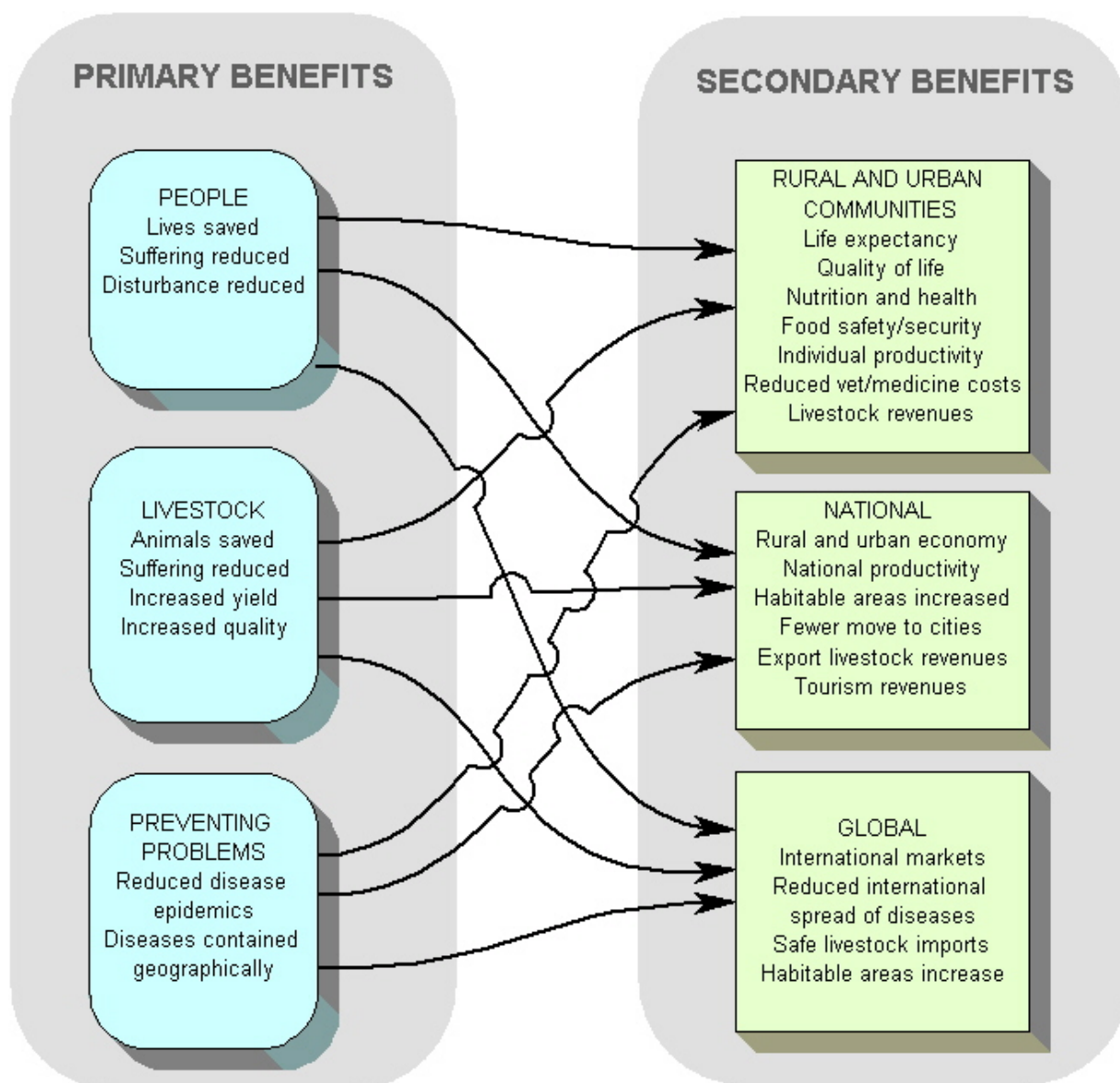


Figure 3. Benefits of Pesticide Effect 2. Controlling human and livestock disease vectors and nuisance organisms.

Published evidence of benefits from Pesticide Effect 2.

Human disease vectors

In public health, insecticides are used to control the insects that spread deadly diseases such as malaria (Delacollette, 2004) that results in an estimated 5000 deaths each day (Ross, 2005). Lindblade (2004) argues that this figure urgently needs to be reduced by use of treated bed nets – particularly the high levels of infant mortality. Yadav (2001) reported that bed nets treated with deltamethrin significantly

reduced indoor resting density, biting, light trap catches, human sourced engorgement rate and parous rate of malaria infection in *Anopheles* mosquitoes. Malaria incidence was reduced 59% in the treated net village, 35% in the untreated net village, and 9% in the no-net village. Curtis (2003) reported that use of treated bed nets reduced the number of infective bites per person per year by 75%. Half of this effect is attributable to a mass effect of reducing mosquito populations due to the nets killing those attracted to the human 'bait'. The other half of the effect is due to the personal protection afforded by the treated nets.

Croft (2001) reported the value attributed to treated nets by the British Army when deployed in tropical countries. Bed nets and screens treated with a pyrethroid insecticide were highly effective in protecting against nocturnally active, anthropophilic arthropods (including ectoparasites), and reduced the incidence of malaria, lymphatic filariasis and Chagas disease. He also reported a reduced incidence of leishmaniasis – a disease which is on the increase in more developed regions such as Latin America and the Mediterranean regions Maroli (2004).

Lindblade (2004) pointed out that insecticide treated bed nets significantly reduced infant mortality in western Kenya with no increased mortality in older children through delayed acquisition of immunity to malaria (an argument sometimes used against use of nets). Townson (2005) concluded that although vector control has proven highly effective in preventing disease transmission, it is not being used to its full potential. His team pointed out that for many diseases, vector control is the only means of protecting populations from infection.

A mathematical model by Maroli (2004) of the spread of leishmaniasis, found that insecticidal control of sand flies represents a more effective way of reducing leishmania infant transmission than the present strategy of culling infected dogs. Gratz (1994) had reached the same conclusions for control of dengue, yellow fever, Japanese encephalitis, malaria, leishmaniasis, and filariasis i.e., that control of the vectors is the most effective approach and insecticides are the basis for nearly all control campaigns. Curtis *et al.* (2002) reported that 10 million people in Vietnam were protected by treated nets where insecticide is provided as a free public health service. Untreated nets were less effective because they did not reduce vector populations. Hanson and his team in Tanzania found that cost per treated net year of US\$ 13.38 was far less than the cost per death averted associated with treated nets. This (cost per death) figure of US\$ 1559 takes no account of the personal misery and suffering caused by the death, but shows that even on purely economic grounds the health campaigns are very justified. Mrigesh (2004) came to similar conclusions in India where, using different calculations, he concluded that the cost of each averted death was only \$52 for insecticide treated nets. Gaves (1998) modelled the costs and came to similar conclusions although vaccines (if they were to be available for malaria) would be even more economic. Goodman *et al.* (2001) found that both treated nets and house wall spraying with residual insecticides worked well in Natal.

Guyatt (2002) concluded that, unlike the London School of Hygiene and Tropical Medicine analysis that suggest residual spraying of walls is more expensive than treated nets, indoor residual spraying (IRS) is actually less than the cost of

insecticide treated nets for malaria control (0.88 dollars per protected person, compared with 2.34 dollars) but these authors agree that the insecticide-based techniques are effective in reducing disease spread by insect vectors. Guyatt (2002a) concluded that sleeping under a treated bed net reduced the risk of infection by 63% (58–68%) and sleeping in a room sprayed with insecticide reduced the risk by 75% (73–76%). Rose too (2001) acknowledged the important role of insecticides in public health and called for new registrations of suitable insecticides for this important programme.

Kroeger *et al.* (2003) reported that eliminating the transmission of Chagas disease, along with substantially reducing its vectors, has a highly favourable cost: benefit ratio. Insecticide-treated bed nets killed 100% of *Rhodnius* bugs (vectors of Chagas disease) compared with only 25% observed mortality in houses using untreated bed nets. A report by the World Health Organisation edited by Decollete in 2004 recommended that 'integrated vector management' techniques should include use of both insecticide-based vector control techniques (i.e., insecticide treated bed nets and indoor residual spraying with insecticides).

More than 100 million people live in areas prone to malaria epidemics in the African continent alone and vector control is the primary way of reducing malaria's terrible toll. Van Geertruyden *et al.* (2005) reported that pregnant women in Rwanda are at particular risk from malaria. The disease accounts for 43% of all deaths and women are particularly susceptible when pregnant. Although use of insecticide-treated bed nets can be effective, actual usage rate of treated bed-nets is low. The nets are inexpensive by many standards, but expensive to the poor women in Rwanda. The authors state that the option of providing free insecticide-treated bed nets to pregnant women should be explored and they should possibly be issued at earlier attendance to antenatal clinics. This would have clear benefits for the women's health.

Bhatia (2004) wrote that malaria is one of the leading causes of morbidity and mortality in the developing world and a major public health problem in India. In use, insecticide-treated nets have proved to be effective in reducing malaria mortality and morbidity in various epidemiological settings. Comparing insecticide-based treatments (treated nets versus residual spraying in houses) both control strategies were shown to be effective in preventing malaria over the base-case scenario of early diagnosis and prompt treatment. Treated nets were more cost effective but may need a low-dose frequent re-treat regime where nets are washed many times per year (Millar, 1999). Lindsay (1989) pointed out the beneficial side effects of permethrin treated bed nets, which eliminated bedbugs and chicken lice, reduced the rate of acquiring head lice and reduced numbers of day-flying and crawling insects.

Voorham (1997) offered a different but effective technique using lambda-cyhalothrin impregnated wide-mesh gauze to cover openings in house walls. This measure alone reduced malaria prevalence from 25-37%.

Ross (2005) reviewing the use of DDT in the Lancet considered the possible adverse health effects associated with prolonged exposure but concluded that “the more pressing problem is 5000 deaths per day (over 1m per year) from malaria”.

Benton (1998) reported on a cost benefit analysis of the African Programme for river blindness (onchocerciasis) control. He concluded that the programme of ivermectin distribution and larviciding was highly cost-effective (return of 17% based solely on blindness prevented) and that cost benefit is even higher if the nuisance biting, skin-related symptoms and impact on productivity are taken in to account.

Livestock disease vectors

Disease control strategies are crucially important for livestock too. Kamuanga (2001) in Burkina Faso reported that tackling trypanosomiasis through tsetse control programs using insecticide-impregnated targets and pour-on treatments of all cattle with deltamethrin 1% resulted in benefits which included; a 25% increase in herd size and an increase in the number of oxen from 0.1 to 1.1 per household; a reduction in mortality from 63.1% to 7.1% and reductions in the rates of abortions and stillbirth of 55.9% and 51.3%, respectively; and an increase in the rate of live births of 57.6% and in the milk yield from 0.2 to 2.2 litres/cow per day in the dry season. Shukken (2004) agreed that both insecticide treated target and insecticide pour-on control programs were associated with lower trypanosomiasis infection incidence in cattle compared with previous time periods without tsetse control. Cattle treated with insecticide benefit because parasite attack is reduced.

Singh (1983) reported that acaricide dips used in Australia to control cattle ticks produced bodyweight gains of 35-45kg/head and significant financial net gains. Windsor (1992) working in South America found that alpacas treated with ivermectin to control external and internal parasites gained 3kg more and their fleece weight 0.36 kg more than untreated animals after 4 months. Net financial gain per male animal was US \$3.54. Pesticides are also needed by poultry farmers to control poultry red mite (Anon, 2005), as well as many other ectoparasites.

Nuisance arthropods

Biting flies not only have an impact as vectors, but also as nuisances that annoy, reduce the quality of life, hinder productivity, depress tourism, and in some cases prevent people living and working in a particular area. Nkot *et al.* (2005) reports 1800 *Simuliid* blackfly bites per person per day in Central Cameroon – a figure that decreased to 730 after fogging with actellic. Grillet *et al.* (2005) reported daily biting rates of up to 3,300 in Venezuela and Brazil. These levels of biting disturb all normal human activity and cause suffering, stress and depigmentation of the affected skin.

PESTICIDE EFFECT 3. PREVENT OR CONTROL ORGANISMS THAT HARM OTHER HUMAN ACTIVITIES AND STRUCTURES

Context

Pesticides are also widely used in a variety of other settings, some of which most of the general public are not aware of. In the same way that pests in agriculture and public health cause undesirable effects such as losses, spoilage and damage, various organisms, when unchecked, have a negative impact on human activities, infrastructure and the materials of everyday life. Pesticides play an important, if often unseen role in preventing this negative impact.

Overview of primary and secondary benefits

The transport sector makes extensive use of pesticides, particularly herbicides. These herbicides are used to ensure that roads, railways and waterways are kept free of vegetation that might cause a hazard or nuisance. For example if vegetation is allowed to grow too tall on roadsides, it reduces the drivers' view at junctions, and deposits branches or vegetation onto the road that might be an obstruction or make it very slippery. The use of pesticides to manage this vegetation brings secondary benefits of safer transport systems with fewer accidents and less stress for users.

The destructive power of vegetation is also enormous; above ground growth around metal structures harbours moisture and can accelerate corrosion, and below ground, the roots of growing plants can crack pipes, open up potholes in the road or dislodge railway lines. Most people living in towns take for granted that roads, gutters and pavements stay clear and weed-free, and are not aware that it is due to the judicious use of herbicides. Thus pesticides bring primary benefits associated with preventing these problems, which lead to secondary benefits of reduced maintenance costs and increased road safety.

Pesticides are also used on watercraft to prevent the build up of algae, molluscs, and weeds, and deliver secondary benefits of reduced costs of manual cleaning, and increased fuel-efficiency from the reduced drag of a clean hull.

In an age of increasingly sedentary jobs, sport and recreation are very important for people's physical and mental health. Herbicides and insecticides are used to maintain the turf on sports pitches, cricket grounds and golf courses and so help to bring secondary benefits of improved health and fitness, reduced stress, and greater quality of life.

Similarly, the pesticides used in domestic gardens enable householders to maintain their plants – edible or ornamental – and protect them from pests and diseases. Gardening is the most popular leisure activity in the United Kingdom and pesticides are helping to facilitate a hugely popular pastime that provides fresh air and exercise for millions of people around the world, contributing to their health, fitness and quality of life. The result of their efforts is reflected economically as pleasant gardens add significantly to the value of properties. Ornamental plants and trees in public

spaces are also protected from pests and diseases by the use of pesticides where necessary. This civic vegetation makes urban landscapes more pleasant to live in, thus improving life quality and reducing stress. Plants provide shade in hot countries and windbreaks in exposed sites which can reduce cooling or heating costs and hence energy expenditure.

Insecticides protect buildings and other wooden structures from damage by termites and wood boring insects, thus decreasing maintenance costs and increasing longevity of buildings and their safety. This use also has wider environmental benefits in that timber – a renewable resource that can be produced in an environmentally beneficial way, becomes a viable construction material.

Antimicrobial pesticides are substances or mixtures of substances used to destroy or suppress the growth of harmful micro-organisms such as bacteria, viruses, or fungi on inanimate objects and surfaces that can cause spoilage, deterioration or fouling of materials in applications such as cooling towers, jet fuel, paints and treatments for textile and paper products. Secondary benefits are greater shelf life and longevity and reduced maintenance costs.

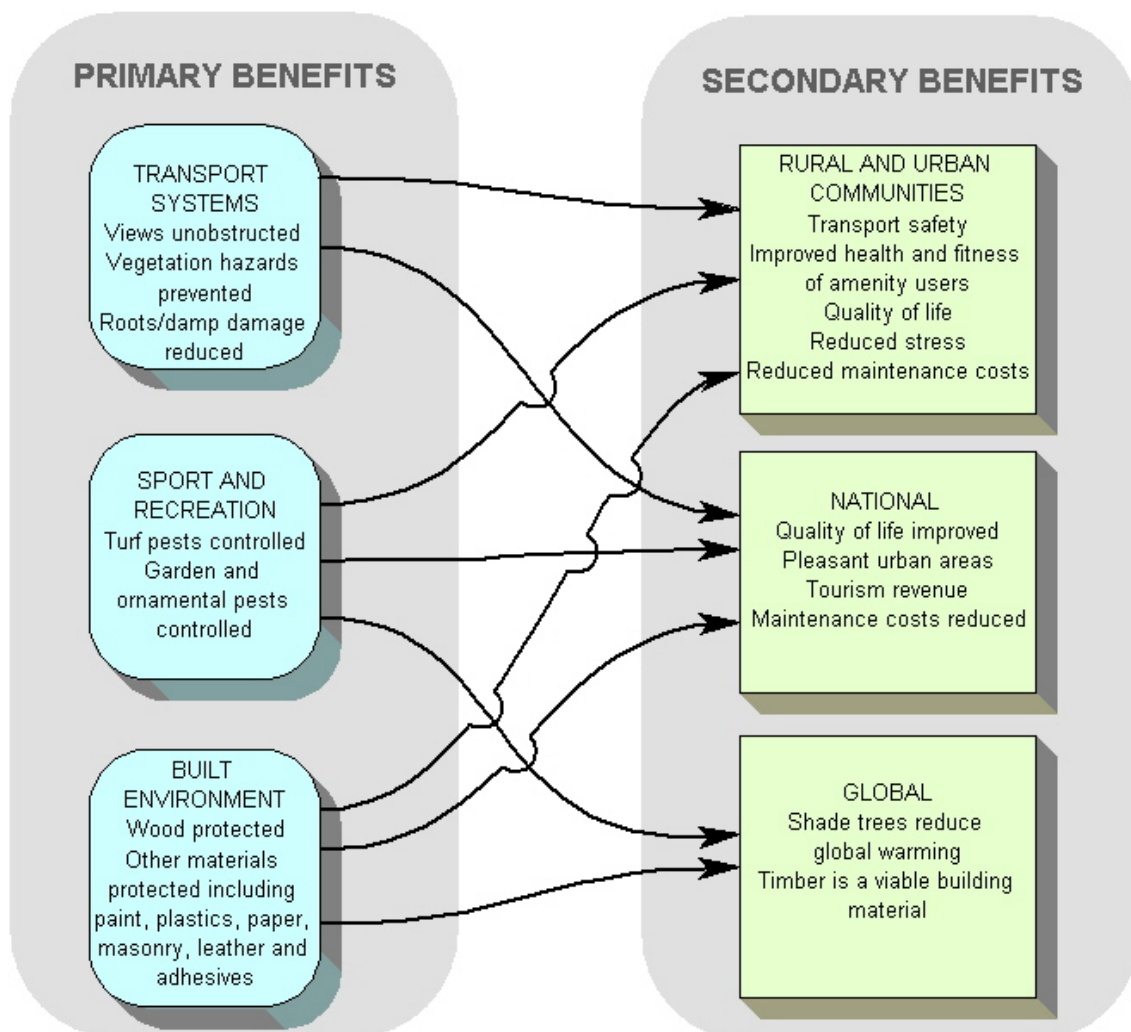


Figure 4. Benefits of Pesticide Effect 3. Prevent or control organisms that harm other human activities or structures.

Published evidence of benefits from pesticide effect 3.

Transport

Pesticides play a crucial role in maintenance of transport systems. This applies to railways, roads, airports and waterways. Torstensson (2001) reported that in Sweden weeds need to be removed from around railway tracks to avoid the risk of train wheels skidding, causing longer acceleration distances and, more seriously, extended braking distances, which could result in the train being unable to stop at signals. Also if weeds on the railway embankment become dry during the summer, there is always a risk of fire caused by sparks from the wheels. In addition, the quality of wooden sleepers is rapidly destroyed when they are lying in polluted water-saturated ballast.

Manual removal of weeds around the track would be possible but apart from the manpower required, it is a dangerous operation. The risk of accidents caused by stumbling or slipping on weeds is obvious and may have fatal consequences. Also weed removal has to be carried out on tracks without disrupting the rail traffic. As a result, the Swedish National Rail Administration has found that weed removal by chemical means (commonly glyphosate and imazapyr) is the only practical and economically realistic method and overall is also the least risky method.

Antuniassi *et al.* (2004) reported that presence of weeds can block drains and make maintenance of tracks more difficult in Brazil, where railways make use of similar types of equipment to that used in agriculture to apply herbicides. They used simulations to calculate that sprays could be made more efficient (cost savings of over 50%) if the habitat variability is taken into account.

Cronk and Fuller (2001) pointed out some of these problems are caused by invasive species. One such plant which invades railways, roadside verges, footpaths, river banks in graveyards, on derelict sites or anywhere that it has been dumped, dropped or deposited is Japanese knotweed (*Fallopia japonica*). It was introduced to the UK as an ornamental plant during the 1800s and has spread widely. Only with intensive and timely application of herbicides can this weed be killed (Child *et al.*, 1998).

Waterways can become blocked by weeds, preventing the flow of water traffic. As with Japanese knotweed, often the species is not a native one, having escaped or been accidentally introduced. For example, the Floating Pennywort, *Hydrocotyle ranunculoides*, a native of North America, has recently become established in Britain and is rapidly becoming a major weed problem at some sites after escaping from garden and aquatic centres. Experiments on the optimum chemical control method have shown that the plant is most susceptible to the herbicide 2,4-D amine, applied at 4.23 kg ha. (Caffey *et al.*, 1999).

Water hyacinth, a floating plant with thick, glossy, round leaves, inflated leaf stems, and very showy lavender flowers was carried from place to place as an ornamental plant or accidentally from its native South America. It has become a serious problem

on some lakes and rivers due to its' rapid reproduction and the fact that it forms dense mats preventing navigation. Biological control has been successful in some places but there is evidence of resurgence in east Africa (Ogwang and Molo, 2003).

Sport and recreation

Pesticides help with creation and maintenance of areas used for sport, walking, picnicking or other forms of leisure. Thomas (2001) discussed use of insecticidal drenches as a tool in landscape management with royal palm bugs being successfully controlled in Florida using a soil drench in the root zone. Templeton *et al.* (1998) cited that residential use (or yard use) of pesticides produces more comfort and safety from pests and better-looking yards, giving aesthetic pleasure, reducing stress and encouraging the playing of sports, and other forms of recreation. Better-looking yards also tend to increase property values, and help to sell homes (Leeming, undated). Pesticides used on gardens can increase the quantity or improve the quality of edible produce and flowers. If they prevent plant mortality, pesticides enable the treated plants to continue to abate noise, moderate temperature, and serve other environmental functions in the yard such as shade, thus reducing cooling expenses as well.

Powel and Lindquist wrote in 1997: "Insecticides and miticides will continue to be the main components of integrated pest management programmes on ornamental plants for the foreseeable future. There simply are no other pest management tactics that will totally replace pesticides at this time".

The built environment

Buildings and structures that use wood, such as fences, railway sleepers, pontoons and jetties are subjected to continuous attack by micro-organisms, shortening their useful life. Antimicrobial pesticides are substances or mixtures of substances used to destroy or suppress the growth of these harmful micro-organisms such as bacteria, viruses, or fungi on inanimate objects and surfaces, for example floors and walls, (EPA undated). Antimicrobial pesticides act as preserving agents in paints, metalworking fluids, wood supports, and many other products to prevent their deterioration. Wood preservatives are particular examples that reduce the rate of tissue degradation by making the food source inedible to organisms that cause rots (Forintek Corporation, undated). Preserving wood extends the life of the timber and properly preservative-treated wood can have 5 to 10 times the service life of untreated wood. This extension of life saves the equivalent of 12.5% of Canada's annual log harvest.

Various treatment methods and types of chemicals are available, depending on the attributes required in the particular application and the level of protection needed. The most commonly used wood preservative in North America for decades has been chromated copper arsenate (CCA), although this may change since CCA began phasing out of most residential applications in January 2004, to be replaced by amine copper quat (ACQ) and copper Azole (CA). Borates are another class of waterborne preservative gaining in popularity. Borates are colourless, non-toxic to humans, and can be applied to wood with or without pressure to stop attack by termites and other boring pests.

Other antimicrobial products are used to control growth of algae, odour-causing bacteria, bacteria which cause spoilage, deterioration or fouling of materials and include products used in cooling towers, jet fuel, paints, and treatments for textile and paper products.

DISCUSSION AND CONCLUSIONS

The exercise of analysing the range and nature of benefits arising from pesticide use has been a mixture of delving, dreaming and distillation. There have been blind alleys, but also positive surprises. The general picture is as we suspected; there is publicity, ideological kudos and scientific opportunity associated with ‘knocking’ pesticides, while praising them brings accusations of vested interests. This is reflected in the imbalance in number of published scientific papers, reports, newspaper articles and websites against and for pesticides – a ratio of over 40:1.

Nevertheless, there is quite a large body of evidence out there once the delving began, and despite casting the net wide, it is certain that we have not found all relevant articles. One reason is that there are many documents stored in information resources not accessed by the main literature search engines. Another reason is that searches are based on specific words, and a relevant article might, by chance, not use any of the search terms used. For example, a scientific article might use the specific name of the pesticide studied, rather than the word pesticide, or insecticide, herbicide etc.

The dreaming refers to the secondary benefits, where we tried to imagine all possible positive outcomes, be they short, medium or long term, and local, national or international. Once these were identified, further searches were carried out for articles to support the hypotheses. Clearly we were not going to find evidence to support all steps in some of these convoluted pathways. For example, imagine that we postulated a benefits pathway such as:

Pesticides control pests→
crops protected→
greater yields→
greater family income→
ability to pay school fees→
higher educational levels→

This is a plausible chain of events, but we are unlikely to pick up a single document if we search for scientific articles with the words pesticides and school fees, because it spans such a wide range of disciplines – chemistry, economics, sociology, education – where would it be published? Even a search using Google only picks up a negative article reporting that farmers who stop using pesticides are able to afford school fees.

Hence our approach has been to find solid, quantifiable evidence of effects and primary benefits, then to extrapolate to secondary benefits. If stronger linkages were

required it would be possible to look for publications not necessarily related to pesticides, but linking the primary effects to secondary ones. For example, a Metalib all text search on “higher yields” and “school fees” turns up several relevant articles supporting the link. Google too comes up with an article by Roger Buckland that includes the following statement “... the graphs highlight the variability in average output over the past two decades or so. This has serious consequences for small-scale peasant farmers whose total output is often barely sufficient to meet household food needs, let alone to allow for any sales to generate cash for such needs as school fees or clothing”. Thus, the pesticide/yield evidence added to the yield/school fees evidence provides an indirect, but documented, link from pesticides to school fees.

One could take this and similar indirect beneficial linkages further and search for relationship between the use of pesticides, educational level and later income or quality of life. We believe that a separate additional report exploring these more subtle social and societal benefits would be a useful counter to some of the anti-pesticide reports that use anecdotal examples or un-cited sources (and many have dubious scientific foundation). However this approach would have been peripheral to the brief to which we were working, and would be better served by a separate report.

We found the process of trying to visually illustrate the benefits pathways useful. The graphic summarising all linkages in an organogram (Figure 1) serves to demonstrate the complexity of interactions and the impressive range of positive outcomes associated with the use of pesticides, but is not necessarily useful for tracking benefit pathways. However, the Excel spreadsheet shown in Appendix 1 can be followed easily and we consider this to be a dynamic matrix that can be updated or modified as necessary.

The colour coding for types of benefit i.e. economic, social or environmental reveal the fact that at community level, most of the benefits are social, with some compelling economic benefits too. At the national level, the benefits are principally economic, with some social benefits and one or two environmental benefits. It is only at the global level that the environmental benefits really come into play.

Although there are no green squares in the community benefits area, to some extent this is an over-simplification as a result of trying to group the benefits and avoid repetition. The benefit of reduced soil erosion and moisture loss that currently sits in the National benefits area, applies equally to communities.

Several highlight examples of pesticides bringing significant benefits arose. There is an opportunity to make these personal and bring them to life with real case studies – something for the future. These examples included:

- The use of fungicides for late blight control. In many locations and seasons such as East and Southern Africa, tomato and potato farmers cannot produce without fungicides. In some other situations, fungicides lengthen the window of production such that those farmers who manage to keep producing into the rainy season enjoy a ten-fold increase in prices. There are strong economic and social benefits of fungicide use here.

- Herbicide use in small scale agriculture in the tropics. These liberate labour for other activities, reduce the drudgery of hand-weeding, reduce the fuel required for mechanical cultivation, and allow communities hit hard by HIV/AIDS to keep weeds under control over a larger area than hand weeding would allow. Again this example brings strong economic and social secondary benefits, coupled with the environmental benefits of reduced greenhouse gases, reduced soil disturbance, erosion and moisture loss.
- Vector and nuisance insect control. Saved lives are a compelling argument for this use of insecticides. Resource-poor communities are ravaged by a wide range of fatal and debilitating diseases and parasites spread or caused by arthropods, including malaria, onchocerciasis, filariasis, Dengue fever, Yellow fever, diarrhoeal diseases, trachoma, leishmaniasis and sleeping sickness. These act as brakes on economic and social development, especially in Africa. Insecticide Treated Nets are a good example of a targeted and efficient pesticide application, and when coupled with Indoor Residual Spraying, the burden of diseases and nuisance insects is greatly reduced. Tourism is important for developed and developing world and vector control can boost revenues.
- Control of invasive species that can cause devastating damage in the absence of their natural enemies, and can damage biodiversity of indigenous ecosystems. These include water hyacinth and rats but there are other examples. In this way, pesticides bring powerful environmental benefits when used to control egress and introductions of pests.
- Control of migrant pests such as locusts – particularly desert locusts. These can cause catastrophic crop loss and can move across national and continental boundaries with ease. There are few effective options – only pesticides have the portability, efficacy, speed of action and work rate to reverse upsurges or tackle plagues. There are also social consequences – the uncertainty caused by locust plagues contributes to people in affected areas moving to town to seek more secure livelihoods.

The study has used a hierarchical structure for analysing and thinking about the benefits of pesticides. A convincing body of evidence has been accumulated that would be difficult to dismiss. For the future, the structure could be further developed to further explore downstream benefits pathways. Personal, geographically relevant case studies could be developed and expanded into human interest stories, presented with high impact graphics and illustrations. Each of the areas in the section above could be expanded in this way and a bank of such articles would be a useful complement to this more scientific and literature-based treatment.

In summary, this report presents a large body of evidence of the value of pesticides. The list of beneficial outcomes from the rational use of pesticides is long and provides compelling support for the hypothesis that pesticides will continue to be a vital tool among the range of technologies that maintains and improves living standards for people throughout the world.

APPENDICES

Appendix 1. Matrix of primary and secondary benefits

CATEGORY	PRIMARY BENEFIT	SECONDARY BENEFIT																											
		Farm and agribusiness revenues	Nutrition and health improved	Food safety	Food security	Quality of life improved	Wider range of viable crops	Labour freed for other tasks	Life expectancy increased	Reduced vet and medical costs	Reduced stress	National maintenance costs	Export revenues	Workforce productivity	Agromomic advice improves cropping	Migration to cities reduced	Pleasant urban areas	Fewer transport accidents	Assured safe and diverse food supply	Less pressure on uncropped land	Fewer pest introductions elsewhere	Habitat for tourism elsewhere	Biodiversity increased	Reduced international disease spread	Shade trees reduce global warming	Timber is viable in construction			
PESTICIDE EFFECT 1. CONTROLLING PESTS AND PLANT DISEASE VECTORS	Agricultural produce	Improved crop/livestock yields	■	■	■	■	■					■	■	■					■	■	■								
		Improved crop/livestock quality		■	■	■							■	■	■														
		Reduced fungal toxins		■	■	■																							
		Improved shelf life of produce	■		■	■	■							■	■														
	Retailer networks established	■												■															
	Energy needs	Reduced drudgery of weeding				■		■						■	■														
		Reduced fuel use for weeding	■										■									■							
		Reduced soil disturbance													■														
	Preventing problems	Pests contained geographically																				■							
Invasive species controlled																							■						
PESTICIDE EFFECT 2. CONTROLLING HUMAN & LIVESTOCK DISEASE VECTORS & NUISANCE ORGS.	People	Human lives saved				■							■	■								■	■						
		Human suffering reduced				■								■	■								■	■					
		Human disturbance reduced				■								■	■								■	■					
	Livestock	Animals saved	■			■							■	■							■								
		Animal suffering reduced								■					■														
		Increased livestock yields	■	■									■	■	■														
Increased livestock quality				■								■	■																
Avoid probs	Diseases contained geographically																							■					
PESTICIDE EFFECT 3. PREVENT OR CONTROL ORGS. THAT HARM OTHER HUMAN ACTVS. & STRUCTURES	Transport	Drivers view unobstructed								■																			
		Tree/bush/leaf hazards prevented																				■	■						
		Roots/damp damage prevented											■																
	Sport and recreation	Recreational turf protected				■																							
		Garden plants protected				■																							
		Civic ornamentals protected				■																					■		
Built environment	Wooden structures protected											■									■						■		
	Masonry/paint/plastics/fuel etc											■																	
			Community level benefits										National benefits					Global benefits											

SECONDARY BENEFIT COLOUR KEY	■ = economic	■ = social	■ = environmental
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Appendix 2. Toxicity

Some of the older generation pesticides such as parathion are very toxic and must be used very carefully. But most products registered for use on crops necessarily break down quickly and have disappeared by harvest time. Other commonly used pesticides are, on paper at least, less poisonous than one might expect when measured as an acute dose given to rats. In the table below a bigger value for the LD₅₀ illustrates that more is needed to kill half the tested animals. In the case of salt the acute dose is surprisingly low at 3000 mg (3 g) per kilo of body weight. The average 80 kg person would be at great risk of being killed by 0.25 kg (250 g) of salt. The common headache drug, paracetamol is three times as poisonous as glyphosate, the herbicide that is most used worldwide. Caffeine looks relatively lethal, yet despite the fact that only about 16 g of caffeine would kill 50% of people there is no warning prescribed on the label. One argument cited about 'natural' things being safer is not supported by the fact that some naturally occurring chemicals are very poisonous indeed. Only a tiny fraction of a gram of ricin is enough to kill several people. In contrast spinosad, one of the new generation of insecticides derived from a fungus that lives in soil, would need a relatively large 40 g to kill half the people, and is therefore of relatively low risk to users and consumers.

<i>Chemical</i>	<i>Oral LD₅₀ to rats (mg/kg body weight)</i>
Nicotine	50
Caffeine	200
Aspirin	1750
Table salt	3000
Paracetamol	1205
Cypermethrin (insecticide)	250-4150
Glyphosate (herbicide)	>5000
Mancozeb (fungicide)	>5000
Spinosad (new insecticide)	3738-5000
Chlorpyrifos (insecticide)	100 - 300
Ricin (natural poison produced by castor oil plant)	0.00003

Table 1. Toxicity of some chemicals.

BIBLIOGRAPHY

Aberg, Ewert Weeds, Weed Control and Problems Connected with Production, Proceedings of the 17th Swedish Weed Conference, Weeds and Weed Control, Department of Plant Husbandry and Research, Uppsala Sweden, Vol. 1, 1976.

Abert, Maryline, *et al.* Anti-Mildious: Bien Plus d'Anthocyanes et de Resveratrol et Moins de Mycotoxines, *Phytoma - La Defense des Vegetaux*, No.554, P.33 Novembre, 2002.

Adipala, E., *et al.* A Review on Options for Management of Cowpea Pests: Experiences in Uganda, *Integrated Pest Management Reviews*, Vol. 5, P.185. 2000. Agrios, George N. *Plant Pathology*, IV Edition, 2002. ISBN 0120445646, Academic Press, London.

Akogun, O.B., M.K. Akogun; Z. Audu Community-perceived benefits of ivermectin treatment in northeastern Nigeria, *Social science & medicine*, Vol. 50, No.10, P.1451. 2000.

Aliyu, L., S.T.O. Lagoke Profitability of Chemical Weed Control in Ginger (*Zingiber officinale* Roscoe) Production in Northern Nigeria, *Crop Protection*, Vol. 20, P.237. 2001.

Antuniassi, U R., Velini, ED and Nogueira, H.C. Soil and weed survey for spatially variable herbicide application on railways. *Precision Agriculture*, 5, 27-39, 2004.

Anon Fighting Weed and Insect Pests to Reduce UK Food Imports, *International Pest Control*, Vol. 18, No.1, P.15 January/February, 1975

Anon Herbicide Use Essential to Crop Production, *Chemical market reporter*, Vol. 263, No.18, P.4, 2003.

Anon. Conservation Technologies and the Plant Science Industry Managing Natural Resources Sustainably. *CropLife reference library*, 2004 (a).
http://www.croplifeasia.org/ref_library/conservationAgriculture/Conservation%20Technologies%20and%20Plant.pdf

Anon. Water matters for sustainable agriculture. *CropLife* 2004 (b).
[http://www.croplife.org/library/attachments/2ec8d87a-8e71-40f2-8343-8c3b276f68ab/7/Water%20Case%20Studies%20\(April%202004\).pdf](http://www.croplife.org/library/attachments/2ec8d87a-8e71-40f2-8343-8c3b276f68ab/7/Water%20Case%20Studies%20(April%202004).pdf)

Anon Pesticides benefits, *Chemical week*, Vol. 159, No.43, P.40. 1997. Economic considerations can overrule normal cancer risk limits for pesticides.

Anon Powdery Mildew Impacting on Wine Quality, *Wine Industry Journal*, Vol. 19, No.6, P.71 November-December, 2004.

Anon Unique anti-fly programme breaks life cycle , Poultry World, 2005 Vol. 159, No.5, P.22

Anon. Ingenuity thrives in battle to beat pests and rodents, Poultry World, Vol. 159, No.7, P.28. 2005.

Armitage, M.S. and C.E. Brook The Case for Weed Control to Spearhead Improvements in Maize and Cotton Husbandry in Swaziland, Proceedings 1976 British Crop Protection Conference, P.165, 1976.

Arthura, Frank, Bisong Yueb ; Gerald E. Wilde Susceptibility of stored-product beetles on wheat and maize treated with thiamethoxam: effects of concentration, exposure interval, and temperature, Journal of Stored Products Research , Vol. 40, P.527-546. 2004.

Austin R B (1998). Yield of wheat in the UK: Recent advances and prospects. Annual Meeting of the crop Science Society of America.

Avery Dennis February 17, 1999 The New York Times

Ayala Garcia, J. , J.L. Bermejo Corrales Control of Cercospora Beticola by Combination of Fungicides with Double Tolerant Cultivars (Rhizomania and Cercospora), Proceedings of the First Joint IIRB-ASSBT Congress, International Institute for Beet Research & American Society of Sugar Beet Technologists, San Antonio, United States of America, P.351,2003.

Aubertot, J.N., J.S. West, L. Bousset-Vaslin, M.U. Salam, M.J. Barbetti and A.J. Diggle Improved resistance management for durable disease control: A case study of phoma stem canker of oilseed rape (Brassica napus) European Journal of Plant Pathology (2006) 114: 91–106

Babu, S.C. , P. Subrahmanyam; D.N. N'gongola Economic Analysis of Yield Losses Due to Diseases- A Case Study of Early Leaf Spot of Groundnut in Malawi, African Crop Science Journal , Vol. 3, No.1, P.105. 1995.

Balsari, Paolo, Gianfranco Airoidi Evaluation of the Mechanical Weed Control in Maize and Soybeans, Proceedings of the 8th European Weed Research Society Symposium: Quantitative Approaches in Weed and Herbicide Research and their Practical Application, European Weed Research Society, Wageningen, Netherlands, P.341,1993.

Bate, Roger Northern country regulation can kill those in the Third World., Economic affairs, Vol. 20, No.3, P.56 September, 2000.

Bates, G. and Denton, H.P. (undated) No-till Establishment of Forage Crops Agricultural Extension Service. The University of Tennessee at: <http://www.utextension.utk.edu/publications/spfiles/sp435c.pdf>

BBC http://www.bbc.co.uk/food/food_matters/organicfood.shtml

Behera, Basudev, Gauri Shankar Singh Studies on Weed Management in Monsoon Season Crop of Tomato, Indian Journal of Weed Science, Vol. 31, No.1+2, P.67. 1999.

Bell, J (2005) Speech "Sense of proportion vital in determining food risk" by the chief executive of the UK's Food Standard Agency (FSA)

Benton, B. Economic impact of onchocerciasis control through the African Programme for Onchocerciasis Control: an overview, Annals of tropical medicine and parasitology, Vol. 92 supplement 1, No.April, P.S33. 1998.

Bernard, Jean-Louis, Virginie Rameil Evolution de la Consommation de Produits Phytosanitaires: Exemples des Herbicides Cereales et des Herbicides Mais,Phytoma: La Defense des Vegetaux, No.584, P.22Juillet-Aout, 2005.

Bernard, Jean-Louis, Virginie Rameil Insecticides Diminutions, pour des Raisons Diverses,Phytoma - La Defense des Vegetaux, No.584, P.26Juillet-Aout, 2005.

Bhardwaj, Shakti S., S.L. Sharma Chemical Control of Fruit Rot and Leaf Blight of Bell Pepper in India,Agriculture, Ecosystems and Environment, Vol. 14, P.151,1985.

Bhatia, Mrigesh R., Fox-Rushby, J and Mills, M Cost-effectiveness of malaria control interventions when malaria mortality is low: insecticide-treated nets versus in-house residual spraying in India, Social Science and Medecine, Vol. 59, P.525. 2004.

Bigler, F., H.R. Forrer; P.M. Fried Integrated Crop Protection and Biological Control in Cereals in Western Europe,Proceedings of an International Conference Organized by the IOBC/WPRS, Biological Control and Integrated Crop Protection: Towards Environmentally Safer Agriculture, Veldhoven, Netherlands, P.95,1992

Branch, W.D., S.M. Fletcher No-Pesticide preliminary Yield Trials in Peanut, Peanut Science, Vol. 28, P.21. 2001.

Bridges, David C. Crop Losses Due to Weeds in Canada and the United States - 1992, Weed Science Society of America. 1992.

Brown, Ian UK Pesticides Residue Committee Report 2004 (available online http://www.pesticides.gov.uk/uploadedfiles/Web_Assets/PRC/PRCannualreport2004.pdf also available on request).

Brunelli, A., *et al.* Efficacy of Strobilurine Derivatives Against Grape Powdery Mildew in Northern Italy, Proceedings of the Brighton Crop Protection Conference - Pests & Diseases, British Crop Protection Council, Brighton, UK, P.137. 1996.

Bruns, Arnold Controlling Aflatoxin and Fumonisin in Maize by Crop Management, Journal of Toxicology TOXIN REVIEWS , Vol. 22, No.2, P.153-173. 2003.

Bugiani, R., P. Cavanni; I. Ponti an Advisory Service for the Occurrence of Phytophthora Infestans on Tomato in Emilia-Romagna Region, EPPO Bulletin, Vol. 23, P.607,1993.

Bulit, J., R. Lafon Powdery Mildew of the Vine, in Spencer, D.M. (ed.), The Powdery Mildews, Academic Press, London, P.525,1978.

Byford, W.J. A Suvey of Foliar Diseases of Sugarbeet and Their Control in Europe, Proceedings of the 59th IIRB Congress, International Institute for Beet Research, Brussels, Belgium, P.1,1996.

California Governor Gray Davis signed into law AB 1493 (commonly known as the "Pavley law") setting legislation to reduce global warming pollution from motor vehicles.

Canada's Guide to Healthy Living at http://www.hc-sc.gc.ca/fn-an/food-guide-aliment/index_e.html

Carlson DH and Eggerding PJ 2006 Surface Fatal accidents - Causes & Appropriate Counter-Actions. <http://www.mine-safety.mtu.edu/ftp/fatals/sevenzero.pdf>

Caudwell, R.W. The Successful Development and Implementation of an Integrated Pest Management System for Oil Palm in Papua New Guinea, Integrated Pest Management Reviews, Vol. 5, P.297, 2000.

Chee, K.H. Recent Development in Rubber Disease Management, Proceedings of the 3rd International Conference on Plant Protection in the Tropics, Malaysian Plant Protection Society, Genting Highlands, Pahang, Malaysia, Vol. 4, P.88,1990.

Chen, Hong, Zhongmei Chen; Yongshu Zhou Rice Water Weevil (Coleoptera: Curculionidae) in Mainland China: Invasion, Spread and Control, Crop Protection, Vol. 24, P.695. 2005

Chenkin, A.F. Economic Effects of Plant Protection in the Russian Federated Republic, Papers at Sessions, VIII International Congress of Plat Protection, Moscow, USSR, Vol. 2, P.27,1975.

Chikoye, D, V.M. Manyong; R.J. Carsky; F. Ekeleme; G. Gbehounou; A. Ahanchede Response of speargrass (*Imperata cylindrica*) to cover crops integrated with handweeding and chemical control in maize and cassava, Crop Protection , Vol. 21, P.145-156. 2002.

Chikoye, David, Steffen Schulz; Friday Ekeleme Evaluation of Integrated Weed Management Practices for Maize in the Northern Guinea Savanna of Nigeria, Crop Protection, Vol. 23, P.895. 2004

Chikoye, David, Udensi E. Udensi; A. Fontem Lum. Evaluation of a New Formulation of Atrazine and Metolachlor Mixture for Weed Control in Maize in Nigeria, *Crop Protection*, Vol. 24, P.1016. 2005.

Child L.E. Wade M. and Wagner M. (1998) Cost effective control of *Fallopia japonica* using combination techniques *Plant Invasions: Ecological Mechanisms and Human Responses*

Clark, M.S., Ferris H.; Klonsky K.; Lanini W.T.; van Bruggen A.H.C.; Zalom F.G. Agronomic, economic, and environmental comparison of pest management in conventional and alternative tomato and corn systems in northern California, *Agriculture, Ecosystems and Environment*, Vol. 68, P.51. 1998.

Clark, M.S., Ferris H.; Klonsky K.; Lanini W.T.; van Bruggen A.H.C.; Zalom F.G. Agronomic, economic, and environmental comparison of pest management in conventional and alternative tomato and corn systems in northern California, *Agriculture, Ecosystems and Environment*, Vol. 68, P.51, 1998.

Coffey, M.D. Integrated Control of Phytophthora Bud Rot and Premature Nutfall of Coconut in Indonesia, *Proceedings of the 3rd International Conference on Plant Protection in the Tropics*, Malaysian Plant Protection Society, Genting Highlands, Pahang, Malaysia, Vol. 5, P.132, 1990.

Coggins, Charles W., Jr. The Value of Plant Growth Regulator Programs to the California Citrus Industry, *Proceedings of the Plant Growth Regulator Society of America, 19th Annual Meeting*, Arlington, Virginia, USA, P.365. 1992. Chemical thinners (reduce the number of developing fruits) improve size and quality

Comis, Don Bait-and-kill strategy can slash insecticide use in Corn Belt, *Agricultural Research*, Vol. 49, No.11, P.16. 2001.

Congressional Budget Office Statement to the Subcommittee on Transportation Committee on the Environment and Public Works, United States Senate October 5, 1977

Cook, R.J., and J.E.E. Jenkins The Contribution and Value of Pesticides to Disease Control in Cereals, *Control of Plant Diseases: Costs and Benefits*, Clifford, B.C. and E. Lester, eds., Blackwell Scientific Publications, Oxford, P.3. 1988.

Cook, R.J., J.E. King Loss Caused by Cereal Diseases and the Economics of Fungicidal Control, in Woods, R.K.S. and G.J. Jellis, *Plant Diseases: Infection, Damage and Loss*, Blackwell Scientific Publications, Oxford, UK, P.237, 1984.

Cooke, L.R. Potato Blight Control in Ireland: A Challenging Problem, *Pesticide Outlook*, Vol. 13, No.4, P.28 November, 1992.

Cramer, H.H. Economic Aspects of Crop Protection *Pflanzenschutz-Nachrichten*, Vol. 28, No.2, P.218. 1975.

Croft AM, Baker D, von Bertele MJ *Med Trop (Mars)*. 2001;61(1):91-8.

Croft, A.M. An evidence-based vector control strategy for military deployments: the British Army experience, *Medecine tropicale*, Vol. 61, No.1, P.91-98 . .

Cronk Q.C.B. and Fuller J.L. (2001) *Plant Invaders – The threat to natural ecosystems* Earthscan Publications World Wildlife Fund

Croplife International at: <http://www.croplife.org/default.aspx>

Cross, J.V., M.J. Marks; A. Greenfield *Weed Control in Integrated Fruit Production*, *Acta Horticulturae*, II International Symposium on Integrated Fruit Production, International Society for Horticultural Science, Veldhoven, Netherlands, Vol. 347, P.169. 1993.

Curtis, Chris, Caroline Maxell *Free insecticide for nets is cost effective*, *Trends in parasitology*, Vol. 18, No.5, P.204-205. 2002.

Curtis, Christopher, Jana-Kara, B.; Maxwell, C.A. *Insecticide treated nets: impact on vector populations and relevance of initial intensity of transmission and pyrethroid resistance.*, *J Vector Borne Dis.*, Vol. 40, No.1-2, P.1-8 . 2003.

Cuthbertson, A.G.S., A.K. Murchie *The Impact of Fungicides to Control Apple Scab (Venturia inaequalis) on Predatory Mite Anystis baccarum and its Prey Aculus schlechtendali (Apple Rust Mite) in Northern Ireland Bramley Orchards*, *Crop Protection*, Vol. 22, P.1125,2003.

Dales, M.J., P Golob *The protection of maize against Prostephanus truncatus (Horn), using insecticide sprays in Tanzania.*, *INTERNATIONAL JOURNAL OF PEST MANAGEMENT*, Vol. 43, No.1, P.39-43. 1997.

Darkwa, E.O., B. K. Johnston, K Nyalemegme, M Yangyuoru, C Boateng, P. J. Terry. *Weed management on Vertisols for small-scale farmers in Ghana*, *INTERNATIONAL JOURNAL OF PEST MANAGEMENT*, Vol. 47, No.4, P.299-303. 2001.

Davis, Mike, Erik Sorensen; Joe Nunez *Carrot Pests and Pesticides*, *Carrot Country*, P.8 Summer, 2000

Davis, R. Michael *The Importance of Pesticides and Other Pest Management Practices in U.S. Tomato Production*, *National Agricultural Pesticide Impact Assessment Program*, <http://cipm.ncsu.edu/piappud/>, 1998.

Dayanatha Jha and Ramesh Chand, *National Centre for Agricultural Economics and Policy Research (ICAR), New Delhi, India from Agro-chemicals News in Brief Special Issue, November 1999 (ref xx)*

Decion, Marianne *Evolution du Desherbage de la Vigne: La Prelevee Toujours au Programme*, *Phytoma - La Defense des Vegetaux*, No.532, P.40 Novembre, 2000

Delacollette (editor), Charles Global Strategic Framework for Integrated Vector Management 2004, World Health Report . 2004.

Demby, W.M. Die Rolle des Pflanzenschutzes bei der steigerung der ertrage der Wichtigsten Kulturen in der VR Polen, Unknown, .

Department of Agriculture, Food and Rural Development Pesticide Control Service, Dublin, Ireland (2000) Pesticide residues in food.

Dietary guidelines for Americans 2005. U.S. Department of Health and Human Services U.S. Department of Agriculture

Diouf, Jacques FAO International Code of Conduct on the Distribution and Use of Pesticides, 2002.

Doughty, K.J., *et al.* Effects of Disease on Seed Quality Parameters of Oilseed Rape Grown for Industrial Uses, Home Grown Cereals Authority, United Kingdom, http://www.hgca.com/cms_publications.output/2/2/Publications/Publications/Publications%20Search.msp?fn=search October, 1998.

Dow Agro, Nalco receive green chemistry awards, Chemical market reporter, Vol. 256, No.1, P.27

Drujiff, A.H., G.J. Kerkhoven The Economic of Hand-Weeding Versus Chemical Weeding in Irrigated Cotton at Galole in Eastern Kenya, Proceedings of the 10th British Weed Control Conference, British Crop Protection Council , Brighton, UK, P.701, 1970.

Eat 5 to 9 a day for better health U.S. Department of Health and Human Services • National Institutes of Health • National Cancer Institute at <http://www.5aday.gov/>

Ebner, L. Considerations on Appropriate Weed Control Concepts for Developing Economies in the Tropics, Heong, K.L., (ed.), Proceedings of the International Conference on Plant Protection in the Tropics, Malaysian Plant Protection Society, P.465. 1982.

Egwuatu, R.I. Field Trials with Systemic and Contract Insecticides for the Control of *Podagrica uniforma* and *P. sjostedti* (Coleoptera, Chrysomelidae) on Okra, Tropical Pest Management, Vol. 28, No.2, P.115. 1982.

Elliot, Sam L., John D. Mumford Organic, Integrated and Conventional Apple Production: Why Not Consider the Middle Ground?., Crop Protection, Vol. 21, P.427, 2002.

Elliott, J.G. Herbicides in Modern Crop Production (b) Extensively Grown Crops, Proceedings of the 9th British Weed Control Conference, British Crop Protection Council, Brighton, UK, P.1053, 1968.

Engels F (1842) The Corn Laws. *Rheinische Zeitung*, December 27.

Englert, W.D., M. Maixner Biological and Integrated Control in European Vineyards, in Biological Control and Integrated Crop Protection: Towards Environmentally Safer Agriculture, Proceedings of an International Conference organized by the IOBC/WPRS, Veldhoevn, Netherlands, Pudoc Scientific, P.39, 1992.

EPA 2002 Pesticides Industry Sales and Usage 2000 and 2001 Market Estimates

EPA (undated) Antimicrobial Chemical Indexes, available on the EPA Pesticide Web site at <http://www.epa.gov/oppad001/chemregindex.htm>.

The European Food Information Council, 2006. Diet, Lifestyle and Life Expectancy. <http://www.eufic.org/fr/heal/heal04.htm>)

Export statistics India from http://www.indiaagronet.com/indiaagronet/Market_upd/Foodgrains.htm

Faivre-Dupaigre, R., J. Rognon Weed Control in Cereals in France: Present Position and Experiments Carried Out in 1964, Proceedings of the 7th British Weed Control Conference, British Crop Protection Council, Brighton, UK, P.136, 1964.

FAO Desert Locust Guidelines 2001, Emergency Centre for Locust Operations, Via delle Terme di Caracalla 00100, Rome, Italy

FAO The State of Food Insecurity in the World 2004, FAO / Economic and Social Department, 2004

FAO Locust Watch at <http://www.fao.org/ag/locusts/en/info/info/faq/index.html>

FAO (HIV/AIDS) <http://www.fao.org/DOCREP/MEETING/004/Y6059E.HTM#5>

Fatality Analysis Reporting System (FARS) of the National Centre for Statistics and Analysis <http://www-fars.nhtsa.dot.gov/> (2006)

FIFRA Federal Insecticide, Fungicide, and Rodenticide Act as amended by the US Food Quality Protection Act of 1996. 7 USC pp 136-141.

Finch, S., R.H. Collier Integrated Pest Management in Field Vegetable Crops in Northern Europe - with Focus on Two Key Pests, Crop Protection, Vol. 19, P.817. 2000.

Five a day – Just eat more fruit and vegetables Public information leaflet, produced by the Department of Health, © Crown copyright 2003 MMM

Forintek Corporation, Canada 'Stopping the rot' <http://www.durable-wood.com/treated/index.php>

- Gattuso, Dana Understanding the Benefits of Pesticides, Consumers research magazine, Vol. 83, No.2, P.34, 2000.
- Geoffrion, Roger Les Plantes Toxiques dans les Cultures,Phytoma: La Defense des Vegetaux, Vol. 532, P.8Novembre, 2000.
- Gianessi, Leonard Beneficial Impacts of Pesticide Use for Consumers,in Ragsdale, Nancy and James Seiber (eds.), Pesticides: Managing Risks and Optimizing Benefits,, American Chemical Society Symposium Series #734, American Chemical Society, Washington, DC, United States of America, P.207,1999.
- Gianessi, Leonard, Nathan Reigner The Value of Fungicides in U.S. Crop Production,CropLife Foundation, Crop Protection Research Institute, http://www.croplifefoundation.org/cpri_benefits_fungicides.htm,2005.
- Gianessi, Leonard, Sujatha Sankula The Value of Herbicides in U.S. Crop Procution,National Center for Food and Agricultural Policy, http://www.croplifefoundation.org/cpri_benefits_herbicides.htm,2003.
- Glaze, Norman Weed Control in Cucumber and Watermelon, Journal of the American Society for Horticultural Science, Vol. 100, No.3, P.207May, 1975.
- Gong, Y.Y, Cardwell, K., Hounsa, Egal, Turner, P., Hall, A., Wild, C P. Dietary aflatoxin exposure and impaired growth in young children from Benin and Togo: cross sectional study. British Medical Journal, 325, 7354, 20 – 21. 2002.
- Goodman, C.A., Mnzava, A.E.P.; Diamini, S.S.; Sharp, B.L.; Mthembu, D.J.; Gumede, J.K. Comparison of the cost and cost-effectiveness of insecticide-treated bednets and residual house-spraying in KwaZulu-Natal, South Africa, Tropical medicine & international health, UK, Vol. 6, No.4, P.280-295 April , 2001.
- Graniti, A. Olive Scab: A Review,Eppo Bulletin, Vol. 23, P.377,1993.
- Gratz, N. G. What role for insecticides in vector control programs?, The American journal of tropical medicine and hygiene, US, Vol. 50, No.6, P.11-20 . 1994.
- Graves, P.P. Comparison of the cost-effectiveness of vaccines and insecticide impregnation of mosquito nets for the prevention of malaria, Annals of tropical medicine and parasitology, Vol. 92, No.4, P.399-410 . 1998.
- Gray, G, Hammitt JK Risk/Risk Trade offs in Pesticide Regulation: An exploratory analysis of the Public Health Effects of a Ban on Organophosphate and Carbamate Pesticides, Risk Analysis , Vol. 20, No.5, P.665. 2000.
- Greene, Duane W. Chemical Thinning to Imporve Fruit Size of Apples, Proceedings of the Plant Growth Regulator Society of America, 26th Annual Meeting,, Arlington, Virginia, USA. 1999. Citrus fruiting can be manipulated using plant growth regulators (marginal interest only)

Greenpeace International (undated) at
<http://www.greenpeace.org/international/campaigns/forests>

Grichar, W.J. , B.A. Besler; A.J. Jaks Use of Azoxystrobin for Disease Control in Texas Peanut, *Peanut Science*, Vol. 27, P.83. 2000.

Griffiths, W. Weed Control in Cereals: A Manufacturer's View of Farmer Benefits, *Proceedings of the 11th British Weed Control Conference*, British Crop Protection Council, Brighton, UK, P.900,1972.

Grillet M.-E., Villamizar N.J., Cortez J., Frontado H.L., Escalona , M., Vivas-Martínez S., Basañez M.G. Diurnal biting periodicity of parous *Simulium* (Diptera: Simuliidae) vectors in the onchocerciasis Amazonian focus. *Acta Tropica*, 94 (2005) 139–158, 2005.

Groninger, John, Sara G. Baer; Didier-Arsène Babassana; David H. Allen Planted green ash (*Fraxinus pennsylvanica* Marsh.) and herbaceous vegetation responses to initial competition control during the first 3 years of afforestation, *Forest Ecology and Management* , Vol. 189, P.161-170. 2004.

Groot, M.J. Economics of Apple Production Systems with Minimal Input of Chemicals, *Acta Horticulturae*, *Proceedings of the XIVth International Symposium on Horticultural Economics*, International Society for Horticultural Science, Guernsey, United Kingdom , Vol. 536, P.47,2000.

Guyatt, H.L., Kinnear, J.; Burini, M.; Snow, R.W. A comparative cost analysis of insecticide-treated nets and indoor residual spraying in highland Kenya, *Health policy and planning*, Vol. 17, No.2, P.144-153 . 2002.

Guyatt, Helen , Snow, Robert W. The cost of not treating bednets, *Trends in parasitology*, Vol. 18, No.1, P.12 - 16 January

Guyatt, Helen, Sarah K. Corlett, Timothy P. Robinson; Sam A. Ochola; Robert W. Snow Malaria prevention in highland Kenya: indoor residual house-spraying vs. insecticide-treated bednet, *Tropical Medicine and International Health* , Vol. 7, No.4, P.298 April, 2002.

Haidar, M.A., .M. Sidahmed ; R. Darwish ; A. Lafta Selective control of *Orobanche ramosa* in potato with rimsulfuron and sub-lethal doses of glyphosate, *Crop Protection* , Vol. 24, P.743-747. 2005.

Hainsworth, S.D. and Eden-Green, S.J. (Eds) *Sustaining Change: Proceedings of a workshop on the factors affecting uptake and adoption of Department for International Development (DFID) Crop Protection Programme (CPP) research outputs.*

Halimah, Muhamad, Yew A. Tan; Bin S. Ismail The Fate of Fluroxypyr in the Soil in an Oil Palm Agroecosystem, *Weed Biology and Management*, Vol. 5, P.184. 2005.

Hanson, Karan, Nassor Kikumbih; Joanna Armstrong Schellenberg; Haji Mponda; Rose Nathan; Sally Lake Cost-effectiveness of social marketing of insecticide-treated nets for malaria control in the United Republic of Tanzania, *Bulletin of the World Health Organization*, Vol. 81, No.4, P.269-276 . 2003.

Hartley, M.J., G.C. Atkinson Effect of Chemical Removal of Barley Grass on Lab Growth Rates, *Proceedings of the 25th Weed and Pest Control Conference*, New Zealand Plant Protection Society, Carlton Hotel, Christchurch, <http://www.hortnet.co.nz/publications/nzpps/proceedings/old/72nzpps.htm>, P.23, 1972.

Hatherill R. Robert (1998) *Eat to Beat Cancer* Renaissance Books

Health 24.com 5 a day for better health at <http://health.mweb.co.za/dietnfood/General/15-742,21352.asp>

Hewitt, H.G. *Fungicides in Crop protection*. ISBN 0 851992013 CAB International

Hibbitt (1990). Putting pesticides into perspective. *Agricultural Engineer*, Summer 1990.

Hohnson, Jr., H., *et al.* Soil Fumigation Found Essential for Maximum Strawberry Yields in Southern California, *California Agriculture*, Vol. 16, No.10, P.4 October, 1962.

Holmes, E. The Contribution of Crop Protection to Increased World Food Supply, *Outlook on Agriculture*, Vol. 3, No.1, P.23. 1960.

Holmes, P.H. New approaches to the integrated control of trypanosomosis, *Veterinary parasitology*, Vol. 71, No.2-3, P.121-135 . 1997.

<http://www.cbo.gov/showdoc.cfm?index=5301&sequence=0>

<http://www.pediatrics.org/cgi/content/full/113/4/S1/1030>

Ibrahim, A.A.S. Efficiency of Some Herbicides for Weed Control in Sugarcane, *Tropical Pest Management*, Vol. 28, No.3, P.255. 1982.

IPPC 1997 International Plant Protection Convention - New Revised Text approved by the FAO Conference at its 29th Session - November 1997)

Irz, X, Lin Lin, Thirtle, C and S Wiggins (2001) Agricultural productivity growth and poverty alleviation. *Development Policy Review* 19(4) 449-466.

Itnal, C.J., B.S. Lingaraju; C.B. Kurdikeri Effect of Herbicides and Cultural Methods on Weed Control in Irrigated Groundnut, *Indian Journal of Weed Science*, Vol. 25, No.3+4, P.27. 1993.

Jadhav 1981 Need to get full ref on withdrawal of insect resistant potato variety due to solanine content. ??

Jennings, E.A., D.S.H. Drennan Economic, Labour Requirement, Crop Safety and Operational Aspects of Trifluralin and Benfluralin, Weed Research, Vol. 19, P.301. 1979.

Jennings, E.A., D.S.H. Drennan Weed Control with Pre-Showing Herbicides in Irrigated Cotton (*Gossypium barbadense* L.) and Groundnut (*Arachis hypogaea* L.) in the Sudan, Weed Research, Vol. 19, P.301. 1979

Kamuanga, M Farmers' perceptions of the impacts of tsetse and trypanosomosis control on livestock production: evidence from southern Burkina Faso, Tropical animal health and production, Vol. 33, No.2, P.141. 2001.

Kanampiu, Fred K. Multi-site, multi-season field tests demonstrate that herbicide seed-coating herbicide-resistance maize controls *Striga* spp. and increases yields in several African countries, Crop protection, Vol. 22, No.5, P.697, 2003.

Kankwatsa, P., *et al.* Efficacy of Different Fungicide Spray Schedules for Control of Potato Late Blight in Southwestern Uganda, Crop Protection, Vol. 22, P.545. 2003.

Kassa, Bekele, Hailu Beyene Efficacy and Economics of Fungicide Spray in the Control of Late Blight of Potato in Ethiopia, African Crop Science Journal, Vol. 9, No.1, P.245. 2001

Kassemeyer, H.H. Integrated Management of Grapevine Diseases and Pests, Proceedings of the Brighton Crop Protection Conference - Pests & Diseases, British Crop Protection Council, Brighton, UK, P.119, 1996.

Keiserukhsky, M.G., O.P. Kashirsky Economics of Plant Protection in the USSR, VIII International Congress of Plant Protection, Papers at Sessions, Moscow, USSR, Vol. 2, P.12, 1975.

Kenkel, Phil, *et al.* Current Management Practices and Impact of Pesticide Loss in the Hard Red Wheat Post-Harvest System, Oklahoma State University, Oklahoma Cooperative Extension Service, <http://cipm.ncsu.edu/piappud/>, Vol. E-930, .

Kennedy, M.H., Meredith, S.E. The effect of 5 years of annual treatment with ivermectin (Mectizan) on the prevalence and morbidity of onchocerciasis in the village of Gami in the Central African Republic, Annals of tropical medicine and parasitology, Vol. 96, No.3, P.297. .

Kevan Bundell Forgotten Farmers: Small farmers, trade and sustainable agriculture. Christian Aid 2002

Kibata, G.N. Participatory Development of Weed Management Strategies in Maize Based Cropping Systems in Kenya, Proceedings of the Thirteenth Australian Weeds Conference, Plant Protection Society of Western Australia, P.343. 2002.

Knutson, Rondal D., *et al.* Economic Impacts of Reduced Pesticide Use on Fruits and Vegetables, American Farm Bureau Research Foundation September, 1993.

Koch, W. Impact of Weeds in Developing Countries , Proceedings of the First International Weed Control Congress, P.127. 1992.

Kolbe, W. Effect of Different Crop Protection Programmes on Yield and Quality of Apples. II (1967-1981), Pflanzenschutz-Nachrichten Bayer, Vol. 35, No.2, P.189, 1982.

Koppelberg, B., H.H. Cramer Control of Mediterranean Fruit Fly *Ceratitis capitata* Weid. in Spain , Pflanzenschutz-Nachrichten, Vol. 22, No.1, P.157. 1969.

Kroeger, Axel, Elci Villegas; Jose´ Ordonez-Gonzalez; Eulides Pabon; Jose´ Vicente Scorza Prevention of the transmission of Chagas' disease with pyrethroid-impregnated materials, American Journal of Tropical Medicine and Hygiene, Vol. 68, No.3, P.307. .

Krystynak, Roland An Economic Assessment of 2,4-D in Canada: The Case of Grain, Canadian Farm Economics, Vol. 18, No.1, P.7. 1984.

Kuan, Chee Yan, *et al.* Crop Losses by Weeds in Malaysia, Proceedings of the Third Tropical Weed Science Society Conference, Malaysian Plant Protection Society, Kuala Lumpur, P.1. 1991.

Kurmawanshi, S.M., R.S. Sharma; T.R. Sahu Studies on Economic Viability of Weed Control with Herbicides in Soybean, Indian Journal of Weed Science, Vol. 27, No.3+4, P.110. 1995.

Kvien, C.K., *et al.* Peanut Production In Systems Restricting Use of Pesticides Based on Carcinogenicity or Leachability, Peanut Science, P.118 July - December, 1993.

Kyelem, D. Impact of long-term ivermectin (Mectizan) on *Wuchereria bancrofti* and *Mansonella perstans* infections in Burkina Faso: strategic and policy implications, Annals of tropical medicine and parasitology, Vol. 97, No.8, P.827. .

Lawrence, Gregor, Judson Leafasia; John Sheridan; Susan Hills; Janet Wate; Christine Wate, Janet Montgomery; Nirmala Pandeya; & David Purdie Control of scabies, skin sores and haematuria in children in the Solomon Islands: another role for ivermectin, Bulletin of the World Health Organization, Vol. 83, No.1, P.34. 2005.

Lawrence, N.J., J. Appel Cereal Fungicides - Past, Present, and Future, Aspects of Applied Biology, Vol. 50, P.263. 1997.

Lee, K.H., *et al.* Effect of Disease and Pest Control on Rice Yield in Relation to Various Combinations of Fertilizer Applications, Korean Journal of Plant Protection, Vol. 12, No.1, P.33. 1973.

Leeming, Nicholas (undated) Director of Propertyfinder.com "Gardens play a hugely important role in selling homes and can add significant value to a property.

Lenne, Jill Pests and Poverty: The Continuing Need for Crop Protection Research, Outlook on Agriculture, Vol. 29, No.4, P.235. 2000.

Lescar, L. Effect of Fungicide Application of Cereals in France, EPPO Bull, Vol. 11, No.3, P.357. 1981.

Lever, Brian G. Crop Protection Chemicals, Ellis Horwood, New York, NY, 1990.

Lewis, Nancy M., Jamie Ruud Blueberries in the American Diet, Nutrition Today, Vol. 40, No.2, P.92 March-April, 2005.

Lewis, Nancy, Jaime Ruud Apples in the American Diet, Nutrition in Clinical Care, Vol. 7, No.2, P.82. 2004.

Likanen, Erkki. The Challenge of Ensuring Safer Cars, 2001 European Commission responsible for Enterprise and the Information Society SPEECH/01/56

Lindblade, Kim A., Thomas P. Eisele; John E. Gimnig; Jane A. Alaii; Frank Odhiambo; Feiko O. ter Kuile; William A. Hawley; Kathleen A. Wannemuehler; Penelope A. Phillips-Howard; Daniel H. Rosen; Bernard L. Nahlen; Dianne J. Terlouw; Kubaje Adazu; John M. Vulule; Laurence Slutsker Sustainability of reductions in malaria transmission and infant mortality in western Kenya with use of insecticide-treated bednets: 4 to 6 years of follow-up, JAMA, Vol. 291, No.21, P.2571-2580 . 2004.

Lindsay, T.A. Permethrin-impregnated bednets reduce nuisance arthropods in Gambian houses, Medical and veterinary entomology, Vol. 3, No.4, P.377. 1989.

Locke, Martin A., Reddy, Krishna N.; Robert M. Zablotowicz Weed Management in Conservation Crop Production Systems, Weed Biology and Management, Vol. 2, P.123. 2002.

Lockwood, Jeffrey A., Richard Anderson-Sprecher; Scott P. Schella When Less is More: Optimization of reduced agent-area treatments (RAATs) for management of rangeland grasshoppers, Crop Protection, Vol. 21, No.7, P.551, 2002.

Lomborg, Bjorn (2001) The Skeptical Environmentalist Cambridge University Press; Reprint edition (August 28, 2001) ISBN: 0521010683

Lomborg, Bjørn (2001) The Skeptical Environmentalist Cambridge University Press; Reprint edition (August 28, 2001) ISBN: 0521010683

Lum, A. Fontem, David Chikoye; S.O. Adesiyan Effect of Nicosulfuron Dosages and Timing on the Postemergence Control of Cogongrass (*Imperata cylindrica*) in Corn, Weed Technology, Vol. 19, P.122. 2005.

Lutman, P.J.W. Objectives of Weed Control in Oilseed Rape, Aspects of Applied Biology, Vol. 23, P.199, 1989.

MAF (Ministry of Agriculture and Forestry) New Zealand. Motivation for Growing Organic Products at <http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/organic-production/organic-farming-in-nz/org30004.htm>

Malaysia has become an important source of oils and fats in the world today, with Malaysian palm oil accounting for 25% of the world's edible oils and fats traded. Although integrated pest management strategies are promoted and implemented in Malaysia, pesticides remain essential tools in the pest management of oil palm plantations.

Manktelow, D.W.L., *et al.* Use Patterns and Economics of Fungicides for Disease Control in New Zealand Apples, Acta Horticulturae, International Conference on Integrated Fruit Production, International Society for Horticultural Science, Cezdzya, Poland, Vol. 422, P.187, 1996

Maroli, M. Prevenzione e controllo dei vettori di leishmaniosi: attuali metodologie, Parassitologia, Vol. 46, No.1-2, P.211-215. 2004.

Martin, P.J., *et al.* Cashew Nut Production in Tanzania: Constraints and Progress Through Integrated Crop Management, Crop Protection, Vol. 16, No.1, P.5, 1997.

Masson, R., H. Reynold; Christophe Roubal Confusion Sexuelle Contre le Carpopapse des Pommes et des Poires: Succes et Limites de la Methode, Phytoma - La Defense des Vegetaux, No.564, P.40 October, 2003.

Maxwell, C.A, E. Msuya; M. Sudi; K. J. Njunwa; I. A. Carneiro; and C. F. Curtis Effect of community-wide use of insecticide-treated nets for 3-4 years on malarial morbidity in Tanzania, Tropical medicine & international health, Vol. 7, No.12, P.1003-1008

Michelakis, Stylianos The Influence of Pests and Diseases on the Quantity and Quality of Olive Oil Production, Olivae, No.30, P.38 February, 1990.

Miller, J.E., A. Buriyo; A. Karugila; J.D. Lines A new strategy for treating nets. Part 1: formulation and dosage, Tropical medicine & international health, Vol. 4, No.3, P.160. 1999.

Miller, James F. Sociological Aspects of Mechanized Farming and Chemical Weed Control, Technical Papers of the FAO International Weed Control Conference, Food and Agriculture Organization, United Nations, Davis, California, P.591. 1970.

Miller, Stanley F. The Effects of Weed Control Technology Change on Rural Communities, Outlook on Agriculture, Vol. 11, No.4, P.172. 1982.

Minuto, Andrea, Angelo Garibaldi; M. Lodovica Gullino Il Basilico come Esempio di Approccio alla Difesa di una Coltura Minore, *Informatore Fitopatologico*, Vol. 5, P.5, 1997

Moore, S 2006 Why organic foods are worth the extra cost
http://www.associatedcontent.com/article/23687/why_organic_foods_are_worth_the_extra.html

Mrigesh, Bhatia, R., Fox-Rushby, J.; Mills, Ann. Cost-effectiveness of malaria control interventions when malaria mortality is low: insecticide-treated nets versus in-house residual spraying in , *Social science & medicine*, Vol. 59, No.3, P.525-539 . 2004.

Nadanassababady, T., O.S. Kandasamy Evaluation of Herbicides and Cultural Method for Weed Control in Cotton, *Indian Journal of Weed Science*, Vol. 34, No.1+2, P.143. 2002.

Nagda, B.L., G.S. Chouhan; Ishwar Singh Effect of Weed Management Practices on Pearl millet Under West Rajasthan Conditions, *International Journal of Tropical Agriculture*, Vol. 9, No.3, P.208 September , 1991.

Nalewaja, John D. Herbicidal Weed Control Uses Energy Efficiently, *Weeds Today* Fall, 1975.

Namanda, S. , *et al.* Fungicide Application and Host-Resistance for Potato Late Blight Management: benefits Assessment from On-Farm Studies in S.W. Uganda, *Crop Protection*, Vol. 23, P.1075. 2004.

Narkiewicz-Jodko, J. Chemical Control of the Onion Fly-*Dellia Antiqua* Meig.-in Poland, *Acta Horticulturae*, International Symposium on Diptera Pests in Vegetable Crops, International Society for Horticultural Science, Skierniewice, Poland, Vol. 219, P.59, 1988.

Naylor, Rosamond Labour-Saving Technologies in the Javanese Rice Economy: Recent Developments and a Look into the 1990's, *Bulletin of Indonesian Economic Studies*, Vol. 28, No.3, P.71 December, 1992.

Ndahi, W.B. Evaluation of Herbicides for Maize Production in Three Ecological Zones of Nigeria, *Tropical Pest Management*, Vol. 30, No.4, P.356

Nene, S.R., *et al.* An Assessment of the Herbicide Technology Extension Project in Sugarcane in K.C.P. Sugar Factory Command Area in Andhra Pradesh, India, *Proceedings of the 11th Conference Asian-Pacific Weed Science Society*, P.497. 1987.

Neuenschwander, Peter Biological Control of the Cassava Mealybug in Africa: A Review. *Biological Control* 21, 214–229 (2001)

Nickolson, P.S., Hirsch PR The effects of pesticides on the diversity of cultural soil bacteria, *Journal of Applied Microbiology* 1998, 84, 551-558, Vol. 84, P.551-58. 1998.

Nkot Baleguel, Avom Alara, Eric Martial, Bikay Raphael Stanislas, Nem Thomas Epey, Baleguel Pierre Didier. Evaluation of the efficiency of two methods of treatment (hot fogging and misting) against cocoa mirides and their impact on blackfly (*simulum damsonsum*) in mbebe village. Report for the Yaounde Initiative Foundation. 2006

Nodtvedt, Ane, Ian Dohoo; Javier Sanchez; Gary Conboy; Luc DesCôteaux; Greg Keefe Increase in milk yield following eprinomectin treatment at calving in pastured dairy cattle, *Veterinary parasitology*, Vol. 105, No.3, P.191. 2002.

Nova Scotia Dept of Agriculture, Fisheries and Aquaculture: Food and Healthy Living at <http://www.gov.ns.ca/nsaf/fhl/index.shtml>

Nuwaha, Fred, Joseph Okware; Richard Ndyomugenyi Predictors of compliance with community-directed ivermectin treatment in Uganda: quantitative results, *Tropical medicine & international health*, Vol. 10, No.7, P.659. 2005.

Nyankanga, R.O., *et al.* Farmers' Cultural Practices and Management of Potato Late Blight in Kenya Highlands: Implications for Development of Integrated Disease Management, *International Journal of Pest Management*, Vol. 50, No.2, P.135 April-June, 2004.

Oerke E-C., Dehne H-W., Schonbeck F., Weber A (1994). *Crop Production and Crop Protection. Estimated losses in major food and cash crops.* Elsevier Science BV

Oerke, E.C., H.W. Dehne *Safeguarding Production - Losses in Major Crops and the Role of Crop Protection*, *Crop Protection*, Vol. 23, P.275. 2004.

Ogwang, J and Molo R., Threat of Water Hyacinth Resurgence after a Successful Biological Control Program *Biocontrol Science and Technology* (September 2004), Vol. 14, No. 6, 623_/626

Okello-Onen, J., A.W. Mukhebi; E.M. Tukahirwa; G. Musisi; E. Bode; R. Heinonen; B.D. Perry; J. Opuda-Asibo Financial analysis of dipping strategies for indigenous cattle under ranch conditions in Uganda, *Preventive veterinary medicine*, Vol. 33, No.1-4, P.241. 1998.

Olanya, O.M., J.J. Hakiza; C.C. Crissman *Potato Production in the Tropical Highlands: Constraints, Fungicide Use, and the Impact of IPM Strategies*, *Outlooks on Pest Management*, P.p. 181 August, 2004.

Olsson, R., T. Nordstrom *Ways Toward Sustainable Sugarbeet Production in Sweden*, *Proceedings of the 65th IIRB Congress*, International Institute for Beet Research, Brussels, Belgium, P.86, 2002.

Omongo, C.A. , *et al.* Insecticide application to reduce pest infestation and damage on cowpea in Uganda, *African Plant Protection*, Vol. 4, No.2, P.91. 1998.

Pacini, Cesare, Ada Wossink; Gerard Giesen; Concetta Vazzana; Ruud Huirne Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis, *Agriculture, Ecosystems and Environment* , Vol. 95, P.273. 2003.

Pande, S. Reviving Chickpea Production in Nepal Through Integrated Management, with Emphasis on Botrytis Gray Mold, *Plant Disease*, Vol. 89, No.12, P.1252 December, 2005.

Parker, J.M.H., R. Vernon Maize Herbicides for Small-scale Farmers in Zambia, *Tropical Pest Management*, Vol. 28, No.3, P.259. 1982.

Pastor, Miguel, and Jaun Castro Soil Management Systems and Erosion, *Olivae*, Vol. 59, P.64 December, 1995.

Patterson, Alastair New Zealand Kiwifruit Annual: 2004, GAIN Report, United States Department of Agriculture, Foreign Agricultural Service, No.NZ4003 February 5, 2004.

Pavley Law 2002 http://www.leginfo.ca.gov/pub/bill/asm/ab_1451-1500/ab_1493_bill_20050222_introduced.html

Paynter, Quentin, Grant J. Flanagan Integrating herbicide and mechanical control treatments with fire and biological control to manage an invasive wetland shrub, *Mimosa pigra*, *The Journal of applied ecology*, Vol. 41, No.4, P.615, 2004.

Peacock, L., G.A. Norton A Critical Analysis of Organic Vegetable Crop Protection in the UK, *Agriculture, Ecosystems and Environment*, Vol. 31, P.187. 1990.

Penrose, Leslie J. Disease Control in Stone Fruits in Australia, *Pesticide Outlook*, Vol. 9, P.13 April, 1998.

Penrose, Leslie J. Disease Control in Stone Fruits in Australia, *Pesticide Outlook*, Vol. 9, P.13 April, 1998.

Peregrine, W.T.H., Kassim bin Ahmad Chemical and Cultural Control of Anthracnose (*Colletotrichum lagenarium*) in Watermelon, *Tropical Pest Management*, Vol. 29, No.1, P.42, 1983.

Pesticides Residue Committee Annual Report, 2004, Available on request, P.1 to 22, 2004. Available by request or online at http://www.pesticides.gov.uk/uploadedfiles/Web_Assets/PRC/PRCAnnualreport2004.pdf

Petacchi, R. Comparison Between Different *Bactrocera Oleae* (Gmel) Control Strategies, *Acta Horticulturae*, Proceedings of the 2nd International Symposium on Olive Growing, International Society for Horticultural Science, Jerusalem, Israel, Vol. 356, P.403,1994.

Petacchi, R., A. Minnocci Olive Fruit-Fly Control Methods in Sustainable Agriculture, *Acta Horticulturae*, Proceedings of the 4th International Symposium on Olive Growing, International Society for Horticultural Science, Valenzano, Italy, Vol. 586, P.841,2002.

Petrusheva, N.I. Protection of Horticultural Crops in the USSR and Future Perspectives, *Papers at Sessions, VIII International Congress of Plant Protection*, Moscow, USSR, Vol. 2, P.124,1975.

Pinstrup-Andersen, Per, Pandaya-Lorch, R Food security and sustainable use of natural resources:, *Ecological economics*, Vol. 26, P.1. .

Ploetz, Randy Black Sigatoka, *Pesticide Outlook*, P.19 February, 2000.

Plumbe, R.P.L., J. Rognon; T. Szoeki Herbicide Development for Weeds in Temperate Crops - A European Perspective, *Proceedings of the First International Weed Control Congress*, International Weed Science Society , Melbourne, Australia, P.311,1992.

Porwal, M.K. Relative Economics of Weed Management Systems in Winter Sweet Potato (*Ipomoea batatas* L.) in Command Area of Southern Rajasthan, *Indian Journal of Weed Science*, Vol. 34, No.1+2, P.88. 2002.

Powell, C.C. and Lindquist, R.K. (1997). *Pest and Disease Manual, Disease, insect and mite control on flower and foliage crops*. 2nd edition. Ball Publishing, Batavia, Illinois, USA. pp 426. (ISBN 1-883052-13-0)

Prematilake, Kapila G., Robert J. Froud-Williams; Punchi B. Ekanayake Weed Infestation and Tea Growth Under Various Weed Management Methods in a Young Tea (*Camellia sinensis* [L.] Kuntze) Plantation, *Weed Biology and Management* , Vol. 4, P.239. 2004.

Priestley, R.H. Fungicide Treatment Increases Yield of Cereal Cultivars by Reducing Disease and Delaying Senescence, *EPPO Bull*, Vol. 11, No.3, P.357. 1981.

Purdue University at :
<http://www.hort.purdue.edu/rhodcv/hort640c/nuse/nu00003.htm>

Puricelli, Eduardo, Delma Facini Effect of soybean spatial arrangement and glyphosate dose on *Anoda cristata* demography, *Crop Protection* , Vol. 24, P.241-249. 2005.

Ragsdale, Nancy N., *et al.* Health and Environmental Factors Associated with Agricultural Use of Fungicides, National Agricultural Pesticide Impact Assessment Program, <http://cipm.ncsu.edu/piappud/>. 1991

Rameshwar, *et al.* Evaluation of Herbicides for Weed Control and Economics in Onion (*Allium cepa* L.) under Cold Desert Region of Himachal Pradesh, Indian Journal of Weed Science, Vol. 34, No.1+2, P.68. 2002.

Rice Mahr, Susan E., L. Joe Moffitt Biologic and Economic Assessment of Pesticide Usage on Cranberry, National Agricultural Pesticide Impact Assessment Program, <http://cipm.ncsu.edu/piappud/>, 1994.

Riches, C.R., Mbwaga, A.M., Mbapila, J., Ahmed, G.J. (2005). Improved weed management delivers increased productivity and farm incomes from rice in Bangladesh and Tanzania. *Aspects of Applied Biology 75: Pathways out of Poverty*. 127-138.

Ricks, Donald, Jerome Hull; Myron Kelsey Impact on the Apple Industry of Reduced Pesticide Usage, Michigan State University, Department of Agricultural Economics, East Lansing, Michigan, Vol. Staff Paper Np. 93-46 March, 1993.

Ridle J (the contact person), The State of Food Insecurity in the World, FAO publications, P.1 to 43. 2004.

Roques, J.F. Weed Control in French Vineyards, *Outlook on Agriculture*, Vol. 9, No.1, P.30, 1976

Rose, Robert Pesticides and Public Health: Integrated Methods of Mosquito Management, *Emerging Infectious Diseases*, Vol. 7, No.1 Feb, 2001.

Ross, Gilbert Risks and benefits of DDT, *The Lancet*, Vol. 366, No.9499, P.1771 November, 2005.

Roubal, Christophe, Bernard Rouille; Marie Cazal *Carpocapse des Pommes et des Poires: ou en est-on en Agriculture Biologique*, *Phytoma - La Defense des Vegetaux*, No.568, P.22 Feb, 2004.

Royle, D.J. Powdery Mildew of the Hop, in Spencer, D.M. (ed.), *The Powdery Mildews*, Academic Press, London, P.381, 1978

Royle, D.J., H. Th. Kremheller Downy Mildew of the Hop, in Spencer, D.M. (ed.), *The Downy Mildews*, Academic Press, London, P.395, 1981.

Saavedra, M., and M. Pastor Weed Populations in Olive Groves under Non-Tillage and Conditions of Rapid Degradation of Simazine, *Weed Research*, Vol. 36, P.1. 1996.

Saba, A. Attitudes towards organic foods and risk/benefit perception associated with pesticides, *Food quality and preference*, Vol. 14, No.8, P.637. 2003.

Safefood Consulting, Inc. Benefits of Crop Protection Technologies on Canadian Food Production, Nutrition, Economy, and the Environment, CropLife Canada, http://www.croplife.ca/foodforthought/_articles_main/documents/pest-benefitfinal-10-05.pdf September, 2005.

Salmon, E.S. The Downy Mildew Problem in Germany, *The Brewers Journal*, P.155 March 15, 1920.

Schmitz, P. Michael Economic Effects of Chemical Use Reduction in European Agriculture,, Institute of Agribusiness, University of GieBen, Germany May, 2003.

Schroder, David, J. Charles Headley; Robert M. Finley The Contribution of Herbicides and Other Technologies to Soybean Production in the Corn Belt Region, 1965 to 1979,, University of Missouri-Columbia, Vol. Agricultural Economics Paper 1981-33, 1981.

Schroder, David, J.C. Headley; Robert M. Finley The Contribution of Herbicides and Other Technologies to Corn Production in the Corn Belt Region, 1964 to 1979, *North Central Journal of Agricultural Economics*, Vol. 6, No.1, P.95 January, 1984.

Schukken, D. Transition models to assess risk factors for new and persistent trypanosome infections in cattle-analysis of longitudinal data from the Ghibe Valley, southwest Ethiopia, *The Journal of parasitology*, Vol. 90, No.6, P.1279. 2004.

Scragg, E.B. Chemical Weed Control in Potatoes, *Scottish Agriculture*, Vol. 44, No.2, P.99 Autumn, 1964.

Seal, K.A.B., Baranowski, M Economic use of pesticides in the , *Pest Management Science*, Vol. 56, P.475.

Seidenfaden, R., A. Fischer; Bonow; D. Ekale; V. Tanya and A. Renz Combined benefits of annual mass treatment with ivermectin and cattle zooprophyllaxis on the severity of human onchocerciasis in northern Cameroon, *Tropical medicine & international health*, Vol. 6, No.9,

Semb Torrensen, K, R.Skuterud ; H.J. Tandsæther ; , M.Bredesen Hagemo Long-term experiments with reduced tillage in spring cereals. Effects on weed flora, weed seedbank and grain yield, *Crop Protection* , Vol. 22, P.185-200. 2003.

Senarathne, S.H.S., .D. SAMARAJEEWA ; K.C.P. PERERA Comparison of different weed management systems and their effects on yield of coconut plantations in Sri Lanka, *Weed Biology and Management* , Vol. 3, P.158-161. 2003.

Settle, Russel F. Evaluating the economic benefits of pesticide usage, *Agriculture, Ecosystems and Environment*, The Netherlands, Vol. 9, P.173 - 185. 1983.

Shabi, E., R. Birger; S. Lavee Leaf Spot (*Spilocaea oleaginea*) of Olive in Isreal and Its Control, *Acta Horticulturae*, II International Symposium on Olive Growing,

International Society for Horticultural Science, Jerusalem, Israel , Vol. 356, P.390. 1994.

Shukla, R.P., P.L. Tandon Bio-Ecology and Management of the Mango Weevil, *Sternochetus Mangiferae* (Fabricius) (Coleoptera: Curculionidae), International Journal of Tropical Agriculture, Vol. 111, No.4, P.293 December, 1985.

Shyamasundar, N Organophosphorus insecticides - benefits and environmental concerns, Chemical business, India, Vol. 13, No.7, P.105 July, 1999.

Sing, N.C. The economics of cattle tick control in dry tropical Australia, Australian veterinary journal, Vol. 60, No.2, P.37, 1983.

Singh, Y., *et al.* On-Farm Weed Control in Rice (*Oryza sativa*) for Higher Production in Mid Western U.P., Indian Journal of Weed Science, Vol. 34, No.1+2, P.126. 2002.

Smith, D.T. , *et al.* Economic Assessment and Fungicide Use on Peanut Seed in the Soutwestern United States, Peanut Science, Vol. 27, P.39. 2000.

Smith, Ron Technology boon to Texas corn growers., Southwest Farm Press, Vol. 30, No.25, P.1 December, 2003.

Some, E.S. The pattern of morbidity and its effects on productivity of factory workers in Kenya, The East African medical journal, Vol. 69, No.11, P.622, 1992.

Sorrenson, Kenneth A., *et al.* The Importance of Pesticides and Other Pest Management Practices in U.S. Strawberry Production, National Agricultural Pesticide Impact Assessment Program, <http://cipm.ncsu.edu/piappud/>, 1997.

Spencer (ed.), D.M. The Downy Mildews, Academic Press, London, 1981.

Sperlingsson, Christer Methods of Weed Control in Sugarbeet - Efficiency, Costs, and Consequences, Weeds and Weed Control, 23rd Swedish Weed Conference, Sveriges Lantbruksuniversitet, Uppsala, Sweden, P.1, 1982.

Stapley, J.H. The Effects of Some Early Synthetic Insecticides on Pest Management Practicies, Outlook on Agriculture, Vol. 10, No.2, P.85. 1979.

Strang, H Changes and challenges facing modern crop protection, New Discoveries in Agrochemicals, Washington, Vol. 892, P.2 to 16. 2005.

Sustainable energy coalition <http://www.sustainableenergy.org/coalition/about.asp>

Svensson, Allan Methods of Weed Control in Cereals - Efficiency, Costs and Consequences, Proceedings of the 23rd Annual Swedish Weed Conference, Department of Plant Husbandry and Research, Uppsala, Sweden, P.10, 1982.

Takeshita, Takafumi, Koji Noritake Development and Promotion of Labor-saving Application Technology for Paddy Herbicides in Japan, *Weed Biology and Management*, Vol. 1, P.61, 2001.

Tamm, Lucius, *et al.* Organic Fruit Production in Humid Climates of Europe: Bottlenecks and New Approaches in Disease and Pest Control, *Acta Horticulturae*, Proceedings of the XXVIth International Horticultural Congress: Sustainability of Horticultural Systems in the 21st Century, International Society for Horticultural Science, Toronto, Canada, Vol. 638, P.333,2004.

Tatchell, G.M. An Estimate of the Potential Economic Losses to some Crops due to Aphids in Britain, *Crop Protection*, Vol. 8, No.2, P.25 February, 1989.

Tattar, Terry Fight Tree Killers, *Landscape Management*, Vol. 41, No.8, P.52 August, 2002.

Tea in Sri Lanka - Weed control with herbicides was superior to that of hand weeding

Templeton, Scott, Zilberman, David; Jick Yoo, Seung An economic perspective on outdoor residential pesticide use, *Environmental science & technology*, Vol. 32, No.17, P.416a.

Terry, P.J. The Use of Herbicides in the Agriculture of Developing Worlds, *Proceedings of the Second International Weed Control Congress*, International Weed Science Society, Copenhagen, Denmark, P.601, 1996.

The Facts for Life UNICEF and other agencies. 175pp, ISBN: 92-806-3664-2

Think Quest The world hunger problem: Facts, figures and statistics
<http://library.thinkquest.org/C002291/high/present/stats.htm>

Thomas, T.A. Royal Treatment, *Landscape Management*, Vol. 40, No.1, P.67. 2001.

Timothy Kiely, David Donaldson and Arthur Grube,

Tolman, J.H., D.G.R. McLeod; C.R. Harris Yield Losses in Potatoes, Onions, and Rutabagas in Southwestern Ontario, Canada - the Case for Pest Control, *Crop Protection*, Vol. 5, No.4, P.227. 1986.

Torstensson, Lennart, Use of herbicides on railway tracks in Sweden, *Pesticide Outlook*, February 2001

Torrise, Salvatore Development and Use of Herbicides in Sicilian Citrus Orchards as a Means for Nontillage Weed Control, *Proceedings of the First International Citrus Symposium*, Riverside, California, Vol. 1, P.479. 1969.

Townson, H, NATHAN, MB; ZAIM, M ;*et al.* Exploiting the potential of vector control for disease prevention, Bulletin of the World Health Organisation , Vol. 83, No.12, P.942-947December, 2005.

Traore, H. , *et al.* Use of Hand-weeding and Herbicides to Control Striga Hermonthica in Burkina Faso, African Crop Science Journal, Vol. 9, No.4, P.645. 2001.

Trewavas, Anthony A Critical Assessment of Organic Farming and Food Assertions with Particular Respect to the UK and the Potential Environmental Benefits of No Till Agriculture, Crop Protection, Vol. 23, P.757. 2004.

Trumble, John IPM: overcoming conflicts in adoption, Integrated Pest Management Reviews , Vol. 3, P.195. 1998.

Tumwine, J., H D Frinking. M J Jeger. Integrating cultural control methods for tomato late blight (*Phytophthora infestans*) in Uganda, Ann. appl. Biol. (), 141:225-236, Vol. 141, P.225-236. 2002.

Tzilivakis, J., Jaggard, K.; Lewis, K.A.; May, M.; Warner, D.J. Environmental impact and economic assessment for UK, Agriculture, ecosystems & environment, UK, Vol. 107, No.4, P.341 - 358. 2005.

UK Gov (2004) House of Commons Select Committee on Health Report – Obesity Published on 27 May 2004 by authority of the House of Commons London: The Stationery Office Limited.

U.N. System of National Accounts; World Bank, World Development Report. 1995

Upton, A.C. (1982). The biological effects of low level ionising radiation. Scientific American, 246, 41- 49.

U.S. Department of Labor Mine Safety and Health Administration at <http://www.msha.gov/stats/STATINFO.HTM>

UDSA at <http://www.ers.usda.gov/AmberWaves/September05/Findings/OrganicPrice.htm> (BHBH)

UK Dept of Transport. New Car Fuel Consumption: Save Money, Save Fuel, Save the Environment, The Department of Transport, July 1995

UK Government (2004) House of Commons Health Committee Report.

UN website: <http://www.un.org/millenniumgoals/>

UNICEF 2005 State of the World's Children <http://www.unicef.org/sowc05/english/index.html>

United Nations <http://www.unicef.org/sowc98/>

United States Department of Agriculture The Importance of Pesticides and Other Pest Management Practices in U.S. Cotton Production, National Agricultural Pesticide Impact Assessment Program, <http://cipm.ncsu.edu/piappud/>, 1993.

US Consumer product safety commission <http://www.cpsc.gov/>

US Environmental Protection Agency <http://www.fueleconomy.gov/> (2006)

US EPA Pesticides: Topical & Chemical Fact Sheet Protecting The Public From Pesticide Residues In Food.

US National Center for Health Statistics, Health, United States, 2005 With Chart book on Trends in the Health of Americans, Hyattsville, Maryland: 2005

USDA Food spending as a proportion of income
<http://www.ers.usda.gov/publications/aer780/aer780f.pdf>

Use of fungicides on cereals in Europe is routine – often two or three foliar applications.

Van Geertruyden, Jean-Pierre, Ntakirutimana, D. Erhart, A., Rwagacondo. A., Kabano, A., D'Alessandro, U. Malaria infection among pregnant women attending antenatal clinics in six Rwandan districts, *Tropical Medicine and International Health*, Vol. 10, No.7, P.681 July, 2005.

Van Huis, A, Meerman F IPM for resource-poor farmers in sub-Saharan Africa, *International Journal of Pest Management*, Vol. 43, No.4, P.313. 1997.

Van Lierde, D., A. Van der Bossche Economical and Environmental Aspects of Integrated Fruit Production in Belgium, *Acta Horticulturae*, Proceedings of the XXVIth International Horticultural Congress: Sustainability of Horticultural Systems in the 21st Century, International Society of Horticultural Science, Toronto, Canada, Vol. 638, P.411, 2004.

Vergheze, Abraham, Tandon, P.L.; Stonehouse, J. M. Economic evaluation of the integrated management of the oriental fruit fly *Bactrocera dorsalis* (Diptera: Tephritidae) in mango in India, *Crop protection*, UK, Vol. 23, No.1, P.61-63 . 2004.

Voorham, J The use of wide-mesh gauze impregnated with lambda-cyhalothrin covering wall openings in huts as a vector control method in Suriname, *Journal of public health*, Vol. 31, No.1, P.9. 1997.

Wagner, Michael R. , Zhong Chen Long-term benefits to the growth of ponderosa pines from controlling southwestern pine tip moth (Lepidoptera: Tortricidae) and weeds, *Journal of economic entomology*, Vol. 97, No.6, P.1972-1977. 2004.

- Wander, J., *et al.* Testing of DSS's to Improve the Control of *Botrytis Cinerea* in Strawberries, *Acta Horticulturae*, Proceedings of the Euro Berry Symposium, International Society for Horticultural Science, Ancona, Italy , Vol. 649, P.241,2004.
- Warren, G.F. Spectacular Increases in Crop Yields in the United States in the Twentieth Century, *Weed Technology*, Vol. 12, P.752,1998.
- Waters, H.R., J. A. Rehwinkel; G. Burnham Economic evaluation of Mectizan distribution, *Tropical medicine & international health*, Vol. 9, No.4, P.A16. 2004.
- Way, M.J, H.F. van Emden Integrated Pest Management in Practice - Pathways toward Successful Application, *Crop Protection*, Vol. 19, P.81,2000
- Weaver, Tara Routing Pecan Scab - Protecting a Popular Nut, *Agricultural Research*, P.8 August, 1998.
- Webster, J.P.G, Bowles, R.G.; Williams, N.T. Estimating the economic benefits of alternative pesticide usage scenarios: wheat production in the United Kingdom, *Crop Protection*, Vol. 18, P.83,1999.
- Webster, J.P.G., and R.G. Bowles
- Webster, J.P.G., R.G. Bowles, and N.T. Williams Estimating the Economic Benefits of Alternative Pesticide Usage Scenarios: Wheat Production in the United Kingdom, *Crop Production*, Vol. 18, P.83. 1999.
- Weibel, F.P., *et al.* Present Status of Organic Fruit Growing in Europe, *Acta Horticulturae*, Proceedings of the XXVIth International Horticultural Congress: Sustainability of Horticultural Systems in the 21st Century, International Society for Horticultural Science, Toronto, Canada, Vol. 638, P.375,2004.
- Weiss, B, Amler, S.; Amler, R.W. Pesticides, *Pediatrics*, USA, Vol. 113, No.4, P.11301 April, 2004.
- Weiss, Bernard. Sherlita Amler and Robert W. Amler 004;113;1030-1036 *Pediatrics*
- Wilson, J.S., Otsuki, T. To spray or not to spray: pesticides, banana exports, and food safety, *Food Policy*, Vol. 29, P.131. 2004
- Windosr, R.S. Economic benefits of controlling internal and external parasites in South American camelids, *Annals of the New York Academy of Sciences*, Vol. 653, No.June, P.398, 1992.
- Winrock International Conservation Tillage Project - Mali, Cote d'Ivoire, Senegal: Annual Report, October 2002. , 2003.
- World Health Organisation 2004 Factsheet 94 Malaria.

World Health Organisation Expert group meeting on aflatoxins and health, Brazzaville, Congo, 24 – 27 May 2005

World Food programme

http://www.wfp.org/food_aid/food_for_hiv/index.asp?section=12&sub_section=2

World Resources Institute. 2006. EarthTrends: The Environmental Information Portal. Available at <http://earthtrends.wri.org>. Washington DC: World Resources Institute.

WWF website (undated) at:

http://www.panda.org/about_wwf/where_we_work/africa/problems/environments/index.cfm

Yadav, Ashok, *et al.* Evaluation of Different Herbicides and Sowing Methods in Cotton, Indian Journal of Weed Science, Vol. 35, No.3+4, P.232. 2003.

Yadav, J.L., R. Chauhan Evaluation of Insecticides Against Larval Population of *Etiella zinckenella* Tr. on Field Pea (*Pisum Sativum* L.), International Journal of Tropical Agriculture, Vol. 18, No.2, P.169 June , 2000.

Yadav, R.S., Sampath, R.R. Deltamethrin treated bednets for control of malaria transmitted by *Anopheles culicifacies* (Diptera: Culicidae) in India, Journal of medical entomology, Vol. 38, No.5, P.613. 2001.

Yallew, Asmare, *et al.* On-farm Evaluation of Alternative Bread Wheat Production Technologies in Northwestern Ethiopia, African Crop Science Journal, Vol. 3, No.4, P.443. 1995.

Yancy J, Cecil H. Study touts herbicide benefits, Southeast farm press, Vol. 32, No.11, P.16, 2005.

Yannick, Ballanger, *et al.* Critical Study of Phytosanitary Practices of a Group of French Farmers, Proceedings of the 10th International Rapeseed Congress, Groupe Consultatif International de Recherche sur le Colza (GCIRC), available at <http://www.regional.org.au/au/gcirc/>. 1999.

Yoldwasser, Y, H. Eizenberg; S. Golan; Y. Kleifeld Control of *Orobanche crenata* and *Orobanche aegyptiaca* in parsley , Crop Protection 22 (2003) 295–305, Vol. 22, No.295-305. 2003.

Zadoks, J.C. Cost Effectiveness of Plant Protection on a National Basis, EPPO Bulletin, Vol. 14, No.3, P.325. 1984.

Zakharenko, V.A. Economics and Prospects of Pesticide Application as Related to the Intensification of Farming, Papers at Sessions, VIII International Congress of Plant Protection, Moscow, USSR, Vol. 2, P.6, 1975.

Zanin, G., A. Berti, and M. Giannini Economics of Herbicide Use on Arable Crops in North-Central Italy, Crop Production, Vol. 11, P.174 April, 1992.

Zettler, J Larry, Arthur, F.H. Chemical control of stored product insects with fumigants and residual treatments, Crop Protection, Vol. 19, P.577. 2000

Zhang, Ze Pu Development of Chemical Weed Control and Integrated Weed Management , Weed Biology and Management , Vol. 3, P.197, 2003.