The Technical and Economic Feasibility of Replacing Methyl Bromide in Developing Countries

Case Studies in Zimbabwe, Thailand and Chile

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Executive Summary

1. *Introduction*

This report presents the results of an international research project involving specialists from diverse countries. Surveys were carried out in Zimbabwe, Thailand and Chile to identify methyl bromide (MB) use patterns. The study reviewed examples of the costs and yields of alternatives and identified technically feasible alternatives where possible. The report also assessed barriers and possibilities for making cost-effective substitutions for MB, and produced a cost-benefit overview, identifying economic opportunities in developing countries, such as new industries to supply alternatives.

Zimbabwe, Thailand and Chile were selected for study because MB is important to key sectors of their economies. The range of commodities and crops treated with MB in the three countries covers many of the uses in developing countries.

2. *Background to Research Project*

2.1 Ozone Layer Depletion

Measurable ozone depletion occurs in most regions of the world, except the tropics. The following examples illustrate the decline in ozone levels over developing countries during the decade to 1991:

- 1-2% ozone decline near Rio de Janeiro, Brazil, increasing to 7-9% at the southern tip of South America;
- 0.5-1% ozone decline near Harare, Zimbabwe, increasing to 3-4% at the southern end of South Africa in the southern hemisphere; and
- 2% ozone decline near Delhi, India, increasing to 4-7% above Beijing, China, in the northern hemisphere (NASA 1992).

Global ozone levels (from 60°N to 60°S) fell by about 4% on average between 1980 and 1994 (WMO 1994:xxx). More recently, springtime measurements in both hemispheres in

1995 and 1996 have shown some of the worst ozone losses on record (WMO 1996). Ozone depletion is expected to peak in the next few years, and recovery will be very slow.

2.2 Human and Economic Costs of Ozone Depletion

By about 1998 at mid-latitudes in the southern and northern hemispheres UV-B radiation levels are expected to become approximately 13% and 11% greater than levels experienced before ozone depletion became significant (WMO 1994). Additional UV-B is expected to have negative effects on human health, health services, farm animals, crop production, forest production, fisheries and tourist industries (Section 2.2). Examples of likely effects of additional UV-B, identified by the World Health Organisation (WHO) and United Nations Environment Programme (UNEP) Environmental Effects Panel include:

- reduced immune responses, which may increase the incidence of infectious disease and may reduce the efficacy of vaccination programmes;
- disrupted growth processes in some plants, leading to reduced yields for certain crops and forest trees, and costs of research to develop new UV tolerant cultivars; and
- disrupted development in fish, estimated to reduce ocean fish stocks by several million tonnes per annum. More than 30% of human food protein comes from the sea (Section 2.2).

2.3 Controls on Methyl Bromide

World Meteorological Organisation (WMO)/UNEP Scientific Assessments have concluded that MB is a significant ozone depleting compound, and that eliminating emissions would have an impact on ozone loss (Section 2.1). The 1994 Assessment calculated that eliminating agricultural and industrial emissions of MB in 2001 would significantly reduce future chlorine/bromine loading in the atmosphere (WMO 1994). Phasing out MB was identified as the largest single step that governments could take to further protect the ozone layer (Table 2.2).

In 1995, Parties to the Montreal Protocol agreed that industrialised countries will phase out MB by 2010 allowing some exemptions, and Article 5 developing countries will freeze consumption by 2002 (based on 1995-98 average consumption) (Section 2.3).

2.4 The Need for Information

Controls on MB are due to be reviewed by the Parties to the Montreal Protocol in 1997. Methyl bromide is important to certain export sectors of Article 5 countries, and it is desirable to have more information about the technical feasibility of alternatives and the possibilities for cost-effective substitutions. Technical and economic information is also needed by enterprises using MB, potential funders and investors (Section 1.3).

This report contributes information in the following areas (Sections 1.1 and 1.3):

- existing and potential alternatives;
- examples of yields and costs of alternatives compared to MB;
- examples of resources needed for introducing alternatives;
- potential sources of financial assistance;
- institutional, market and economic barriers;

- assessment of feasibility and cost-effectiveness; and
- cost-benefit overview, including economic opportunities such as the development of new industries to supply alternatives.

3. *Consumption of Methyl Bromide*

3.1 Consumption in Zimbabwe, Thailand And Chile

Article 5 countries have been estimated to use approximately 14,500 tonnes of MB a year (Section 2.5). Surveys conducted for this research project found that:

- Zimbabwe used at least 600 tonnes MB in 1994 (Section 3.3), and was probably the ninth highest user among developing countries.
- Thailand used about 700 tonnes per annum (1992-94 average) (Section 4.8), and among developing countries was around the eighth highest user of MB.
- Chile used more than 200 tonnes in 1994 (Section 5.3), and probably ranked about twentieth among developing country users.

3.2 Main Applications

Article 5 countries in total have been estimated to use about 70% of MB for soil, about 16% for grain stocks, about 9% for all types of quarantine and pre-shipment (QPS) treatments, and about 5% for miscellaneous uses (Section 3.3). Our surveys found that Zimbabwe and Chile predominantly use MB for soil (Table A below). Chile uses an unusually large proportion of MB as a quarantine treatment for perishable commodities, while Thailand uses an unusually large proportion for durable commodities, mainly grain exports (Table A).

These examples illustrate the fact that use patterns are very diverse among Article 5 countries. However, there are general regional patterns. Countries in Latin America use MB predominantly for soil fumigation; South East Asian countries mainly use it for stored or exported grains; while dominant uses in Africa are soil and grain storage, varying from country to country.

Table A

Consumption of MB in Zimbabwe, Chile and Thailand in 1994 (survey results), compared with estimates for all Article 5 countries in 1992 (TEAP 1995b).

QPS = quarantine and pre-shipment uses

	Estimated MB Consumption -tonnes (%)			
Major Applications of MB	*Article 5 Countries*	*Zimbabwe*	*Chile*	*Thailand*
Soil	10,150 (70%)	515 (85%)	140 (70%)	31 (5%)
Post-harvest except QPS	2,320 (16%)	78 (13%)	0 (0%)	142 (23%)
All QPS uses	1,250 (9%)	10 (2%)	45 (22%)	494[1] (70%)
Misc. uses	780 (5%)	2 (<1%)	16 (8%)	6 (1%)
Total consumption	**14,500 (100%)**	**605 (100%)**	**201 (100%)**	**673 (100%)**

[1] *This includes cases where phytosanitary certificates are required by importing companies, and some may not be QPS as defined by the Montreal Protocol*

3.3 Crops Grown using Methyl Bromide

The project identified the crops and commodities treated with MB by conducting surveys of MB importers and users. In Zimbabwe, for example, the survey covered 102 agricultural producers and 8 organisations (Section 3.3).

Together the three countries use MB for more than 24 crops, predominantly for export. The only soil uses common to all three countries are tobacco seedbeds, cut flowers and nurseries (Table B below).

- In Zimbabwe, MB is used for more than 12 crops; mainly tobacco seedbeds (about 500 tonnes ie. 83% of national consumption), with small amounts for flowers, paprika and nurseries (Section 3.3).
- In Thailand, a small quantity of MB was reported to be used for four soil applications, mainly tobacco (Section 4.10).
- In Chile, MB is used for more than 12 crops, mainly tomatoes and peppers (approximately 130 tonnes ie. about 65% of national consumption), with small quantities for tobacco seedbeds and nurseries (Section 5.4).

Table B

Crops reported to be grown in soil treated with MB in survey countries - percentage of national consumption (1994).

Estimated Percentage of National MB Consumption - % (tonnes)			
Crop Use	*Zimbabwe*	*Chile*	*Thailand*
Crops using 10% or more of national MB consumption	• Tobacco - 83% (550 T)	• Tomato - 55% (110 T) • Pepper - 10% (20 T)	
Crops using 1% -9% of national MB consumption	• Flowers - 2% (12 T) • Paprika - >1% (>1 T)	• Tobacco - 3% (c.5 T)	• Tobacco - 1% (3 T)
Crops using less than about 1% of national MB consumption	• Nurseries for coffee, tomato, citrus, cole, and others • Strawberries	• Nurseries for forest, fruit & nut trees • Seedbeds for lettuce, eggplant, onion, other vegetables	• Cut flowers • Nurseries for coffee • Golf courses

3.4 Stored Products Treated with MB

Methyl bromide is used for more than 7 types of stored grains in the survey countries. The relative importance of MB is fairly typical of the respective regions.

- Zimbabwe used about 78 tonnes MB in 1994 to help protect about 4 main types of stored grains, predominantly maize and wheat (Section 3.4).
- Thailand used at least 142 tonnes MB for at least 5 main stored products, including rice, maize, tapioca, feed grains and pulses (Section 4.11).
- Chile used no MB for stored products.

3.5 Quarantine & Pre-shipment Uses

The survey found MB was used as a quarantine and pre-shipment (QPS) treatment for 9 main durable commodities and about 12 perishable commodities.

- Zimbabwe uses a small amount of MB for QPS, for 6 perishable and durable commodities, such as grains and tobacco (Section 3.4).
- Chile uses >45 tonnes MB for nine export commodities, primarily table grapes, stone-fruit and timber to meet the requirements of USA quarantine authorities (Section 5.3).
- Thailand uses about 500 tonnes MB for quarantine and pre-shipment and phytosanitary purposes, for about 6 main durable commodities (grains) and 3 main perishable commodities (Section 4.11). Grain treatments are often carried out because importing companies require phytosanitary certificates.

4. *Economic Importance of Methyl Bromide*

Methyl bromide was found to have significant economic importance to the agricultural sectors which export fresh produce, tobacco and grains in the three countries. In Zimbabwe and Thailand it is also used to help preserve grain stocks, which are important for food security. Box 1 illustrates the employment and export value of the three main sectors using MB in Zimbabwe.

Box 1

Examples of Economic Importance of MB.

Economic importance of main sectors using MB in Zimbabwe:

1. Tobacco - production and export
   Tobacco had an export value of about US$ 530 million in 1994/95, accounting for 20-25% of Zimbabwe's foreign currency earnings. The sector is a major source of employment, and about 6% of the population depend on the tobacco industry (Section 3.4.1). About 98% of tobacco is grown using MB in Zimbabwe, on 1,800 large-scale farms, and on half of the 1,000 small-scale farms.

2. Grains - storage, import and export
   MB is used by the Grain Marketing Board to conserve grain stocks. It is important for food security, and for export earnings in years when significant quantities of grain are exported.

3. Horticulture - production and export
   Exports of cut flowers, fruit and vegetables from Zimbabwe earned US$ 62 million in 1994/95, and are likely to continue to grow. MB is used by a proportion of large-scale commercial farms as a soil treatment, and occasionally as a quarantine treatment in Zimbabwe or importing countries.

5. *Soil Alternatives*

The Methyl Bromide Technical Options Committee (MBTOC) report did not identify technically feasible alternatives, either currently available or at an advanced stage of development, for less than 10% of MB use in 1991 (MBTOC 1994). MBTOC found that the alternatives to MB are the same in developing countries as in industrialised countries, but developing countries face additional constraints in infrastructure and other conditions (Section 6.3).

5.1. Yields of Alternatives

To be considered effective, alternatives must give adequate yields. Some techniques give lower yields than MB, while others give equal or greater yields. Substrates in particular (natural or synthetic) tend to give significantly higher yields, often about 20% greater for strawberries for example (Section 6.5). Table C below presents examples of alternatives that give greater yields than MB.

Table C
Examples of alternatives that give greater yields than MB.

Alternative system	Crop and country	Crop yield - compared to MB
Natural substrates	Strawberries - Italy	Alternative 60% greater yields
Chemical treatments, plant breeding, etc.	Strawberries open field - Netherlands	Alternative gives 50-100% greater yields
Substrate (peat) allowing double crop	Strawberries covered crop - Netherlands	Alternative 125% greater yields p.a.
Solarisation, IPM	Peppers - Italy	Alternative 20% greater
IPM, composting, steam	Cut flowers - Colombia	Alternative greater
1,3-D fumigant, herbicide	Peppers - Florida trial	Alternative slightly greater

5.2. Technically Feasible Alternatives

The significant pests controlled by MB were examined. In many cases a combination of treatments or procedures is necessary to control the range of pests controlled by MB (Section 3.6). Technically feasible alternatives were identified for all of the crops using MB in Zimbabwe, Thailand and Chile (Table D below) (Section 6.6). Several alternatives were listed for each crop, noting that different users (eg. small and large tobacco growers) have different needs, and that it is desirable to avoid vulnerability from dependence on one method in the future.

5.3 Soil Alternatives in Use

Surveys identified 13 examples of soil alternatives used in Zimbabwe, Thailand and Chile for 8 different crops. Literature reviews identified further cases of existing alternatives, giving more than 50 examples in developing countries (excluding trials) (Table 6.1, Section 6.4). Alternatives in use include integrated pest management (IPM), soil amendments, solarisation, chemical treatments, steam and substrates (soil substitutes), or combinations of these techniques, for crops such as tomatoes, peppers, strawberries, tobacco and flowers. In some cases alternatives are used by a small proportion of growers; in others, use is widespread. Successful alternatives are used on an area of about 4,200 hectares for cut flower production in Colombia, for example (Section 6.4).

TABLE D

Examples of technically feasible soil alternatives, and examples of countries where alternative techniques are used.

Crops (examples)	Examples of technically feasible alternatives	Examples of countries where treatments used
Tobacco seedbeds	Steam treatments	Thailand
	Nematicides, pesticides, burning straw on seedbeds	Thailand, Zimbabwe
	Natural substrates	(Farm trial)
	Hydroponics	USA
Cut flowers	IPM, compost, steam	Colombia
	Steam	Italy, UK
	Substrates	UK
	Solarisation with pesticides	Italy
Nurseries, propagation beds	Substrates and steam	Colombia, UK
	Steam	Zimbabwe
	Bark substrates	Zimbabwe, USA - Ohio
Tomatoes, peppers and vegetables	IPM, with composting in some cases	Chile, Mexico, Guatemala, Sri Lanka, Vietnam, Indonesia, Spain
	Substrates	Zimbabwe, Sicily, Belgium, Germany
	Steam	Italy, UK, Germany
	Solarisation with fumigant or IPM	India, Morocco, Italy, USA - Florida
	Pesticides or fumigants	Zimbabwe, Chile
Strawberries	IPM	Zimbabwe, Guatemala, Germany
	Natural substrates	Italy, Netherlands, Belgium
	Metam sodium and/or other pesticides	South Africa, Netherlands
	Solarisation with IPM	Italy

6. *Alternatives for Durable Commodities*

6.1. Technically Feasible Alternatives

An analysis of the commodities and pests treated with MB identified technically feasible alternatives for all post-harvest uses of MB for durable commodities, excluding quarantine and pre-shipment. In many cases, changes in commodity management practices would be required.

6.2. Alternatives in Use or Approved

The study also identified more than 50 examples where alternatives are used for durable commodities (excluding trials or prototypes) (Tables 6.6 and 6.8). These included 15 different treatments, such as phosphine, in-transit carbon dioxide, hermetic storage and cold treatments (Table E). Phosphine is used in many countries.

7. *Quarantine and Pre-Shipment Alternatives*

Literature reviews identified 41 alternative quarantine treatments for durables approved by quarantine authorities in the USA (Tables 6.9 and 6.10), and a further 90 alternative quarantine treatments approved for perishable commodities by the USA or other countries (Tables 6.14 and 6.15). These provide potential alternatives for quarantine and pre-shipment uses in Zimbabwe, Thailand and Chile (Sections 6.8.3 and 6.9.3).

TABLE E

Examples of technically feasible alternatives for durable commodities, and examples of countries where alternative treatments are used.

Durable products	Technically feasible alternatives are used	Examples where alternatives
Stored grains, legumes		
	Phosphine	Zimbabwe, Thailand, Philippines and many other countries
	Carbon dioxide	Indonesia
	Hermetic storage with other treatment	Philippines, Israel
	Nitrogen	Australia
	Insecticides	Some countries
	Inert dusts, where appropriate	Australia, Canada
	Heat treatments, where appropriate	(Commercial prototype stage)
Export grains, nuts, legumes		
	Phosphine	Thailand, UK
	In-transit carbon dioxide	Australia (groundnuts)
	Flushing retail packs with CO_2 or nitrogen	Thailand (for premium rice)
	Nitrogen	Australia
	Heat treatments	(Prototype stage)
Tobacco		
	Phosphine	Zimbabwe
	Vacuum steam flow process	(Approved by USA quarantine authorities)
	Pre-shipment inspection and certification	
	Methoprene insect growth regulator, for storage	Increasingly used
Wooden items, textiles, crafts, artifacts		
	Heat with constant humidity	UK, Germany, Austria
	Heat treatment for Khapra beetle	(Approved by USA quarantine authorities)
	Phosphine, where appropriate	Philippines
	Nitrogen flow	Germany

8. *Transferability of Alternatives*

The Crop Protection Coalition, a group representing MB users in the USA, has noted that agricultural research in the past has been directly transferable from some crops to others, so 'it is logical to infer that much of the work' on alternatives for crops in major user regions 'will be transferable to other crops and cultural systems in other regions' (CPC 1995).

Some of the existing alternatives can often be transferred directly from one region to another, without need for additional testing in each country. This applies, for example, to certain efficient steam systems and some substrate systems. For stored products, existing treatments such as phosphine or CO_2 can often be utilised without need for additional research. In contrast, existing IPM systems can normally be transferred only within areas where the same pests and conditions occur; some additional work would be required to apply the systems to new areas.

9. *Costs of Alternatives Compared to MB*

The project reviewed studies that compare the costs of MB and alternatives, and commissioned additional cost studies in Zimbabwe and Chile. Some alternatives were found to cost significantly more, whereas others cost the same or significantly less than using MB (Sections 7.2 - 7.8). Examples of specific alternative systems with operating costs similar to or lower than MB are given in Table F.

Each term such as 'steam treatment', 'IPM', 'solarisation' or 'phosphine fumigation' covers a wide range of techniques, and each should be regarded as a family of techniques. We found that different techniques within the same family had very different costs. In most cases where there are expensive techniques, there are also much cheaper options in the same family. So if alternatives are selected carefully it would be possible to introduce alternatives with low to moderate costs. Conversely, alternatives can be unnecessarily expensive if careful selection is not made (Section 7.9).

We also found that the costs of alternatives in sectors or countries where alternatives are well-established were often significantly lower than in countries where they are rarely used (Section 7.9). There are cost-savings from widescale use, and normal market pressures over time have led to improvements in costs and applications.

In the area of stored products, costs can be reduced by changing the supply of key inputs (eg. phosphine). The operating costs of CO_2 treatments for grain, for example, could be reduced by investing in the capture of CO_2 by-products (Section 7.8).

It would be useful to users and funders if UNEP or another independent agency were to compile a database which identifies for each family of alternatives the techniques which are most cost-effective, and areas where costs can be reduced by making technical improvements.

TABLE F
Examples of specific soil alternatives with operating costs similar to or lower than MB.

Specific Alternative	Crop and Country	Cost Compared to Use of MB
IPM/composting	Cut flowers - Colombia	IPM/composting 28% cheaper, and more profitable
IPM/solarisation	Tomatoes - Italy	IPM/solarisation 67% cheaper, and more profitable
IPM/solarisation	Strawberries, various crops - Italy	IPM/solarisation much cheaper, and more profitable
Steam, certain types	Various glasshouse crops	Similar to MB
Seed trays	Seedlings - Zimbabwe	Seed trays cheaper where transport costs low
Substrates, natural & synthetic	Strawberries, cucurbits - Netherlands	Substrates give higher profits than MB
Certain chemical treatments	Runnerbeans - Zimbabwe Strawberries - S. Africa	Chemical systems similar or cheaper

10. Resource Requirements

Resources are primarily required for know-how, training, and building up local industries to supply alternatives. The resources that will be needed are outlined below.

- **Training in alternative methods of pest control and changed management practices.** The transfer of skills and knowledge will in most cases be the most important component in the adoption of alternatives. Training projects have a high completion rate (56%) among projects approved under the Multilateral Fund, and tend to be of shorter duration and less resource-intensive than other projects (UNEP 1994). The large-scale IPM programmes carried out by the Food and Agriculture Organisation (FAO) and Non-Governmental Organisations (NGOs) in developing countries demonstrate the economic benefits and practical feasibility of large numbers of farmers changing agricultural practices (Section 7.6.1). Training also will be important for agricultural advisers and consultants, who have an important role in advising users about suitable techniques.

- **New or extra equipment will be required by users. Equipment for soil and post-harvest alternatives is generally not complex.** Equipment for natural substrates, for example, would include suitable substrates (eg. grain hulls, gravel, agricultural or food industry waste), and plastic sheets, holders or concrete beds. Equipment for steam treatment can include ordinary drainage pipes, a fan and a steam boiler. Equipment for CO_2 grain treatment includes gas-tight sheeting, a pressure-testing device, specialist glue, and a cylinder of CO_2.

- **Additional labour or other costs will need assistance where alternatives have higher operating costs than MB.** Use of phosphine for grain, for example, normally incurs additional chemical costs, additional sheeting and additional demurrage charges.

- **Expertise and research facilities will be needed to improve, adapt or develop alternatives.** This would require researchers with specialist experience of alternatives, facilities of agricultural research institutes in developing countries, and growers/users participation in on-site research. Experts in some developing countries (eg. Colombia) have considerable experience with developing and using alternatives.

- **Establishment of new, local industries to provide products and services for alternatives.** Examples include pest control advisory services, processing of otherwise waste materials to make substrates, manufacture of seed trays, concrete for fixed beds, plastics and fumigation sheets, specialist glues, chemicals, biological control agents and other agricultural equipment.

In cases where alternatives have lower operating costs than MB, there are opportunities for growers to receive good returns on investments. Effective IPM or substrate systems, for example, normally provide growers with significantly better profits after the investment in know-how and equipment has been made (Section 7.6).

11. *Financial Assistance*

Financial assistance would be essential for replacing major uses of MB in developing countries. Sufficient replenishment of the Multilateral Fund would be necessary, and other sources of financial assistance may also be considered where appropriate (see Section 7.12). Potential sources include:

- **Import licence fees.** Governments in developing countries could consider placing import fees on MB and using all revenues for the introduction of environmentally-sound alternatives. Australia has introduced import licence handling fees of about US$70 per tonne of MB, and importers have to pay about US$7,800 for two-year licences (Australian EPA 1995).

- **Voluntary levies.** Some users of MB in developing countries are owned by well-resourced companies (eg. multinationals), and could consider introducing a voluntary levy and donating it to their national Ozone Protection Unit to allocate to smaller users for environmentally-sound alternatives. (Growers in one region of Australia have introduced a voluntary levy of about US$0.15 per kg of MB (Nufarm 1995).)

- **Agricultural programmes.** A number of governments and agricultural and development agencies at present offer assistance to agriculturalists in the form of subsidies, reduced-rate loans, or grants for agricultural production, technology transfer, modernisation, export development or marketing. Relevant programmes could be reviewed to see whether some might be re-oriented to encourage the up-take of environmentally-sound alternatives in order to assist the modernisation of horticulture and other sectors using MB.

- **Training programmes.** A number of governments and other agencies operate agricultural training programmes. Small and large IPM programmes have been carried out in a number of countries. Some programmes could be re-oriented or expanded to help provide training in alternatives to MB.

- ***Agenda 21* programmes.** Countries signing the Earth Summit's Agenda 21 have made a commitment to promote training in IPM and non-chemical methods of pest control (UNCED 1992). Funding issues are under discussion internationally. There will be opportunities to integrate future programmes to implement the IPM objectives of Agenda 21 with programmes to replace MB.

- Some rural development and industrial development programmes could be re-oriented to help provide grants, loans, management programmes, training schemes, or other assistance to establish or expand companies in developing countries to supply alternatives. Programmes which provide loans or funds for export industries could also assist developing countries to establish new export industries to help meet the future demand for alternatives to MB.

12. Economic Opportunities from Replacing MB

The replacement of MB would provide developing countries with a number of benefits and new economic opportunities. One of the major opportunities is the development of new industries in developing countries, to supply local and export markets with alternative products and services. Examples of opportunities to manufacture products include:

- substrates made from otherwise waste materials, such as forest industry waste, crop waste, seafood and grain processing wastes;
- plant extracts, pesticide products;
- biological control agents;
- specialist glues and plastics;
- fumigation sheets;
- steam boilers, heat treatment equipment, fans, etc.; and
- capture and scrubbing of CO_2 by-products.

Examples of opportunities for service industries include:

- soil pest identification and monitoring services;
- consultancy and information services on alternative methods of pest control;
- training programmes;
- research services; and
- pest control treatments, such as mobile steam treatments, fumigation services (Section 7.14.5).

Some existing companies in developing countries have opportunities to expand production or diversify; for example a company making biological control agents in Zimbabwe. Agricultural research facilities in Zimbabwe, Thailand and Chile also have opportunities to expand to provide research, consultancy services and professional training in alternatives for MB users locally and in other countries.

Replacing MB also provides developing countries with opportunities to:

- **Improve crop yields and profitability.** A number of alternatives offer growers opportunities for increasing yields and profitability (Sections 6.5 and 7.2-7.8).

- **Improve competitiveness.** Alternatives used by Colombia flower producers have helped to increase cost-efficiency in an industry that has more than doubled its volume and value of flower exports in the last decade. In contrast to some other flower exporting nations, yields in Colombia are increasing (Section 7.14.2).

- **Modernise horticulture.** Broad spectrum pesticides are increasingly regarded as out-moded methods of pest control, because they destroy both damaging and beneficial organisms. Replacing MB provides opportunities to modernise horticultural sectors. The removal of MB in the Netherlands, for example, was found to have been a catalyst for the widespread adoption and continued development of new agricultural techniques (Section 7.14.2).

- **Increase skill levels in agriculture.** Many of the alternatives would require a higher level of skill among rural workers.

- **Create employment.** Some alternatives replace chemical inputs with more labour, providing opportunities to increase employment (Section 7.14.3). The new industries needed to supply alternatives would also generate employment.

- **Reduce consumption of imported products.** Zimbabwe and Thailand each pay about US$ 1,200,000 for imports of MB each year. Replacing MB provides opportunities for import substitution, so that future expenditure on pest control products and services could benefit industries in developing countries (Section 7.14.6).

- **Increase technology transfer between developing countries.** The expertise and technology of successful alternatives used in developing countries can be transferred to other countries, helping the economies of both partners (Section 8.6).

- **Reduce externalised costs.** Use of MB produces externalised costs, primarily ozone depletion, but also residues in soil, crops and sometimes water (Section 7.13).

A comparison of the costs and benefits of using or replacing MB concluded that for developing countries, greater economic opportunities arise from the development and uptake of modern, competitive alternatives than from continued reliance on MB (Sections 7.13 - 7.16).

13. Commercial and Market Issues

Market pressures are starting to have an impact on MB users in some sectors. For example, some tobacco importers no longer accept MB treatments for tobacco exports from Zimbabwe and some Asian countries, partly because MB can affect the quality of tobacco but also because of its environmental effects.

Other market changes may have an impact on MB use in future. At present many consumers are not fully aware of methyl bromide's role in ozone depletion. When ozone depletion increases in the next few years, consumers may press supermarkets and importing companies to avoid purchasing products treated with MB (Section 7.15.1).

In the USA, products manufactured with CFCs and traded between states normally have to be labeled with a warning statement about ozone depletion. Some groups in the USA and

Europe have started to campaign for similar labeling of products grown with MB, so that the public can choose to avoid such products if they wish (Section 7.15.2).

Such trends indicate that users of MB may experience commercial difficulties in marketing their products in the future as supermarkets and importers respond to market pressures.

14. *Factors that Facilitate Transition*

The Review Under Paragraph 8 of Article 5 of the Montreal Protocol identified major factors that tend to impede or hasten phase-out of ozone depleting substances (ODS) in Article 5 countries (UNEP 1994). The high proportion of MB used for export products (about 88% in Zimbabwe) for example can be expected to hasten phase-out because users will be subject to market pressures from importers and will tend to have better links to information about alternatives according to the review findings. Zimbabwe, Chile and Thailand have a predominance of factors that hasten phase-out, such as export orientation, user organisation, and the existence of National Ozone Protection Units (Sections 8.1-8.3). Exporters in tobacco, horticulture and grain sectors have started to actively investigate alternatives. Funding the replacement of MB in such circumstances is likely to produce a more rapid reduction in MB than would occur in countries without such positive factors (Section 8.4).

Governments may consider taking several steps at the national level to encourage reductions in MB use:

- Adjust controls on MB pesticide product use (under pesticide regulations) to increase the interval between MB treatments and reduce the permitted doses (Section 8.5.1).
- Review the list of crops and products for which MB is permitted under national pesticide regulations, and let approval lapse for uses where pests can be controlled by other methods (Section 8.5.1).
- Review agricultural programmes, subsidies, grants, favourable loans and other forms of agricultural assistance to ensure they do not promote use of MB. Where possible re-orient horticultural or other agriculture programmes to promote environmentally sound alternatives.
- Review quarantine policies, to ensure that use of MB is not required in cases where other suitable disinfestation treatments can be used. Request importing countries to do likewise.
- Identify opportunities for establishing new industries based on alternatives, and set up or re-orient rural development and export development programmes to encourage such industries.

Companies and user sectors can also take measures to reduce consumption of MB in the short to mid-term:

- Some traders and importing companies currently specify in commercial contracts that exporters must fumigate commodities with MB. Contract conditions could in many cases be changed to allow use of other effective methods of pest control.

- Users could examine whether they could alternate MB treatments for soil or stored products with other methods of pest control. This would effectively halve their consumption, and help develop the market for alternatives.

- Where financial assistance is made available, users could examine the potential for reducing doses of MB. For example, the Tobacco Research Board in Zimbabwe has found the traditional dose of MB for tobacco seedbeds could be reduced by half if gas-tight sheets were available (Blair 1995); this could reduce consumption of MB in Zimbabwe by approximately 40%.

However, the marketing and promotional policies of some MB manufacturers and distributors could have a strong negative effect on global efforts to reduce consumption.

15. Feasibility of Reductions and Phase-out

Scientists have calculated that a freeze on MB consumption in Article 5 countries would not prevent an increase in future chlorine/bromine loading to the atmosphere (TEAP 1995), indicating that further controls on MB are desirable. In addition, replacing MB offers developing countries benefits and significant new economic opportunities.

Table G summarises some of the main findings of this study. Technically feasible alternatives were identified for all soil and post-harvest (non-quarantine and pre-shipment) uses of MB in the three countries examined. The alternatives would also be appropriate for similar crops and commodities using MB in many other developing countries. Potential alternatives were identified for quarantine and pre-shipment uses.

The identified alternatives are effective techniques, most of which are in use in some sectors or countries. In some cases alternatives are used by large numbers of enterprises (eg. phosphine in most countries, IPM system in Colombia).

Financial assistance would be required for developing countries to replace major uses of MB; for investment in infrastructure, training and equipment, and for additional operating costs that arise. After the initial investment, some alternatives would have lower operating costs. Cost-effective replacements of MB (in terms of $ cost per ODP-kg replaced) can be made if alternatives are screened to ensure that more expensive techniques within each 'family' are avoided.

The complete replacement of MB for soil and post-harvest uses is technically and economically feasible in Zimbabwe, Thailand, Chile and developing countries with similar uses of MB. The main factors that will determine the rate of reductions and phase-out will be the availability of sufficient financial assistance, market pressures and policies of governments and users.

TABLE G

Summary of conclusions on the technical and economic feasibility of replacing MB.

	Soil Applications	Post-harvest, except quarantine & pre-shipment	Quarantine & pre-shipment
Identification of existing, alternative methods of pest control or disinfestation	A range of alternatives was found to be in use (more than 50 examples in developing countries alone)	A range of alternatives was found to be in use (more than 50 examples in developing and industrialised countries)	A range of alternatives was found to be approved or in use (130 examples)
Identification of technically feasible alternatives	Pests and crops using MB were analysed; technically feasible alternatives were identified for all crops in the countries studied	Commodities and pests treated with MB were analyzed; technically Feasible alternatives were identified for all commodities in the countries studied	Potential alternatives were identified
Main resource requirements	Financial assistance would be necessary for adapting or applying alternatives at local level, and primarily for skill/knowledge transfer; after the initial investment, some alternatives have lower operating costs	Financial assistance would be necessary for training and additional costs of equipment, changed procedures etc; further development work needed to optimise some alternatives (eg. heat treatments); long-term grain storage using alternatives can be cheaper than using MB	Financial assistance necessary for further research, development, trials and lengthy negotiations for gaining official approval
Cost-effectiveness	Commonly used alternatives offer opportunities for many cost-effective replacements of MB ($ per ODP-kg replaced)	Alternatives such as phosphine and CO_2 offer opportunities for many cost-effective replacements of MB ($ per ODP-kg replaced)	May have higher relative costs than replacements for soil and stored products
Technical and economic feasibility of replacing MB	Feasible for almost all crops and pests if sufficient resources are made available and alternatives are selected with care	Feasible for almost all commodities and pests if sufficient resources are made available, alternatives are selected carefully and commodities are well managed	Economic feasibility not assessed

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CHAPTER 1

Aims of the Report

1.1. *Aims of Report*

This report provides information about the pattern of use of methyl bromide (MB) in Zimbabwe, Thailand and Chile, and existing and potential alternatives. It will examine the following issues:

- Crops and commodities for which MB is used;
- Quantity of MB used;
- Pests of concern to MB users;
- Value and structure of sectors using MB;
- Existing and potential alternatives suitable for the situations in the case study countries, including a description of alternatives identified by the United Nations Environment Programme's (UNEP) Methyl Bromide Technical Options Committee (MBTOC) report;
- Examples of the costs of using alternatives compared to MB;
- Examples of resources (equipment, expertise and funding) necessary to develop, improve or introduce alternatives for key sectors;
- Factors that tend to promote or impede potential reductions or phase-out of MB; and
- Technical feasibility and economic implications of replacing MB, under various scenarios.

1.2. *Research Methods*

Specialists in the three study countries were commissioned to undertake surveys to identify MB consumption, user sectors and existing and potential alternatives. Specialists were also commissioned to compile case studies comparing the cost of using MB and alternatives, and to analyse the collected data.

This report utilised the following research methods: literature reviews; interviews with appropriate experts in the study countries and elsewhere; surveys of MB users and research groups to identify uses of MB and existing/potential alternatives; surveys to identify pests, conditions and control techniques; analysis of collected research data; and peer review.

1.3. The Need for Information

The 1994 UNEP/World Meteorological Organization (WMO) Scientific Assessment reported that eliminating the agricultural and industrial emissions of MB would produce a significant reduction in the levels of chlorine/bromine reaching the stratosphere in future years (WMO 1994:xxiii). In 1995 the Parties to the Montreal Protocol agreed that consumption of MB in Article 5 countries will be frozen by 2002, with the exception of quarantine and pre-shipment uses (Decision VII/3). The 1997 Meeting of the Parties will consider further adjustments to control measures on MB (Decision VII/8).

Developing countries are concerned about the impacts that controls on MB may have on agricultural exports, a major source of national income. This has been a major factor in discussions during the Montreal Protocol meetings in 1994 and 1995.

UNEP's MBTOC report has noted that alternatives to MB in developing countries are the same as in industrialised countries (MBTOC 1994:284). However, MBTOC pointed out that Article 5 countries have, in general, characteristics that may affect the economic and technical feasibility of the implementation of alternatives. The report stated that resources such as technological capacity and infrastructural attributes in Article 5 countries tend to be less developed. Article 5 countries may also have more urgent social needs and are more dependent on the agricultural sector than most industrialised countries (MBTOC 1994:285).

The MBTOC report has identified a wide range of existing and potential alternatives. This information can be applied to the specific pests, sectors and conditions of Zimbabwe, Thailand and Chile. In addition, case studies on the performance and costs of alternatives in these countries can help to provide information about the technical and economic implications of replacing MB in developing countries.

Additional information about the technical feasibility and costs of alternatives would be beneficial at several levels:

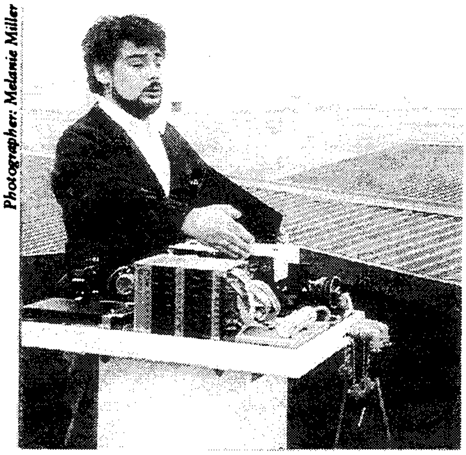
1) To help inform discussions on further adjustments to controls on MB, at the national level and under the Montreal Protocol. A number of Parties have expressed the need for more information about the technical and economic issues arising from controls on MB.

2) To help inform enterprises using MB in Article 5 countries, including SMEs and parastatals. Some exporters who use MB are already experiencing market pressures (mainly from importing companies) to replace MB. Yet users often do not have information about alternatives. The Review Under Paragraph 8 of Article 5 of the Montreal Protocol found market forces will not contribute to timely action on ozone depleting substances (ODS) unless critical actors (such as technology producers, suppliers and users) receive sufficient quantity and quality of information, including reliable data on the technical and financial details of alternatives (UNEP 1994:80).

3) To help inform research activities. MBTOC has noted the need for research to identify alternatives that are effective, environmentally acceptable, easy to apply, safe to users, affordable and specific to local conditions, crops and target pests, as part of a technical strategy necessary for replacing MB in Article 5 countries (MBTOC 1994:293).

4) To help improve the coordination of activities at national and regional level. The Review Under Paragraph 8 of Article 5 noted that Article 5 countries identified lack of information about costs and alternative technologies as one of the impediments to the implementation of country programmes (UNEP 1994).

Photographer: Melanie Miller



Ozone monitoring at the University of Punta Arenas in Southern Chile.

1.4. *Outputs of Research Project*

The case studies and assessment in this report contribute information in the following areas:

- technical information about existing and potential MB alternatives for three countries and others with similar uses;
- identification of alternatives that minimise externalised costs, ie. alternatives that pose the least risk to users, human health and the environment;
- costs of using alternatives compared to MB in selected sectors, and identification of some cost- effective alternatives;
- examples of resources needed for developing, improving or introducing alternatives in selected sectors;
- institutional, market and economic barriers to the development or introduction of alternatives;
- assessment of the feasibility of reducing or replacing MB, under different scenarios;
- opportunities to develop new industries and exports to supply new markets for alternatives to MB; and
- projects requiring funding in case study countries, for the development of alternatives and/or technology transfer.

The study provides information relevant to the following groups: decision-makers involved in the Montreal Protocol; sectors and individual enterprises using MB; enterprises seeking to develop new industries, export products or services; research groups; national Ozone Protection Units and coordination bodies; industrial development bodies; and funders of projects to develop or introduce alternatives.

OVERVIEW

Of Methyl Bromide and Ozone Depletion

THIS CHAPTER PROVIDES AN OVERVIEW OF THE 1994 UNEP SCIENTIFIC ASSESSMENT OF OZONE DEPLETION, AND THE PREDICTED HEALTH, ENVIRONMENTAL AND ECONOMIC EFFECTS OF INCREASED UV RADIATION. IT SUMMARISES NATIONAL AND INTERNATIONAL CONTROLS ON MB. IT OUTLINES THE REASONS FOR THE INCREASING USE OF METHYL BROMIDE (MB) IN DEVELOPING COUNTRIES, AND ITS CURRENT ECONOMIC IMPORTANCE.

2.1. Methyl Bromide's Role in Ozone Depletion

Since 1991, four official scientific assessments have calculated that anthropogenic MB contributes significantly to ozone layer depletion (WMO 1991; UNEP 1992; SORG 1993; WMO 1994). The 1994 WMO Scientific Assessment of Ozone Depletion found that eliminating emissions of MB 'would have a rapid impact on the extent of stratospheric ozone loss' due to MB's short lifetime and potency (WMO 1994:10.23). The Scientific Assessment also noted that the future bromine loading to the atmosphere will depend on choices made about the human production and emissions of MB (WMO 1994:xxiii).

For policy-makers, the most important conclusions of the WMO Assessments are the calculations of future chlorine/bromine loading (called the integrated effective future chlorine equivalent loading). These Assessments estimate the long-term impact on the ozone layer of different actions, such as reducing or eliminating emissions by specific dates.

The 1994 Assessment calculated that eliminating the agricultural and industrial emissions of MB in 2001 could reduce future chlorine/bromide loading by about 13%, compared to the loading from a freeze on consumption (WMO 1994:13.10) (Table 2.1). The calculation took into account the fact that approximately 50% of the agricultural MB fumigant is degraded and not emitted, so it provides a clearer picture of ozone losses than the Ozone Depletion Potential (ODP) alone.

The Assessment identified four areas where the international community could have an impact on ozone losses, in addition to the controls agreed to under the Montreal Protocol in 1992. Eliminating MB was identified as the single largest remaining step that could be taken to reduce ozone losses (Table 2.1).

MB has a short life-time, which means it inflicts its damage rapidly on ozone. As a consequence, early reductions in the use of MB would produce improvements rapidly on the ozone layer, while elimination of chemicals with long lifetimes (eg. CFCs) will bring improvements in the long term. Early reductions in chemicals with short lifetimes would shorten the period of high ozone losses, and would reduce the impact of other ozone depleting substances in the atmosphere, because of synergistic reactions between bromine and chlorine.

The WMO Assessment estimated that each atom of bromine that reaches the stratosphere destroys approximately 50 times more ozone than each atom of chlorine (WMO 1994:xxi). The Assessment calculated that it is improbable that MB's ODP is less than 0.3 or greater than 0.8 (WMO 1994:10.23) The document states that 'There is no single process whose present estimated uncertainty could reduce the ODP below 0.3'. Smaller values could be possible only if two improbable situations occurred simultaneously and several of the parameters were at the extremes of their error limits (WMO 1994:10.22).

In the improbable event that MB's ODP were to be reduced to 0.1, it would be the same as methyl chloroform (ODP 0.1) which is scheduled to be phased out by 1996. There are also ozone depleting substances with ODPs of less than 0.1 which are scheduled for phase-out.

Methyl bromide has both natural and anthropogenic (human) sources. It is not the only ozone depleting substance like this. Methyl chloride, for example, is emitted by the oceans and biomass burning. Natural emissions of chlorine and bromine have occurred for millennia, and are part of the balanced rate of natural ozone break-up and replenishment established over billions of years (NOAA 1992). It is the extra chlorine and bromine - from human activities - that causes the net reduction in ozone levels called ozone depletion. The extra chlorine and bromine break up ozone faster than it can be replaced. From a policy perspective, it is therefore necessary to address the preventable additional emissions.

The WMO Scientific Assessment has examined the suggestion of an 'ocean buffer' to determine whether the oceans might emit an additional, equivalent amount of MB if human emissions were eliminated. The Assessment concluded that ocean 'buffering' is realistically limited to only about 2 or 3% (WMO 1994:10.14).

The 1994 Assessment reported uncertainties about MB's chemistry in the stratosphere have been mostly resolved, although a number of other scientific uncertainties remain (WMO 1994:10.23). This means that scientists are dealing with ranges and estimates, rather than precise figures.

In every area of science, especially those where research started barely twenty years ago, scientists can state that there are large areas of uncertainty, so this is to be expected in the case of MB. The key issue is whether there is sufficient scientific information to determine that MB has a significant detrimental effect on the ozone layer. The WMO Scientific Assessment reconfirmed that anthropogenic MB contributes significantly to ozone depletion, and that eliminating emissions from industry and the fumigant would lead to significant improvements in the future.

TABLE 2.1

The 1994 WMO Scientific Assessment identified four areas where controls in addition to the Copenhagen Amendments could be introduced by the international community to reduce future ozone losses.

Action identified by the WMO Scientific Assessment	Estimated reduction in integrated future ozone losses	TEAP conclusions about the feasibility of further controls
1. MB - Eliminating agricultural and industrial emissions in the year 2001	13% reduction - compared to a freeze on MB in 1994	Technically feasible
2. Halons - Preventing release of halons in existing equipment	10% reduction	Technically feasible, but costly
3. HCFCs - Eliminating emissions by 2004	5% reduction	Technically and economically feasible
4. CFCs - Preventing release of CFCs in existing equipment	3% reduction	Technically feasible, but not economically feasible
Total	**31% reduction**	

Sources: Compiled from WMO 1994:xxiii; TEAP 1995:1-2.

2.2 Health, Environmental, and Economic Impacts of Ozone Depletion

Ozone depletion allows increased levels of radiation from the sun to reach the earth's surface. Additional ultraviolet-B (UV-B) radiation is expected to have negative impacts on human health, plants, animals and ecosystems, and economic implications for health services, agricultural production, forestry, tourism and other industries.

The UNEP report on The Environmental Effects of Ozone Depletion provides an up-to-date scientific assessment of the expected health impacts of increased UV-B radiation (Environmental Effects Panel 1994):

- A sustained 1% decrease in ozone is estimated to increase the incidence of non-melanoma skin cancer by approximately 2%.
- A 1% increase in ozone depletion may be associated with a 0.6-0.8% increase in eye cataracts.
- Additional UV exposure suppresses some immune responses, and may increase the incidence of certain infectious diseases. This could have a significant impact on people with impaired immune function and could reduce the efficacy of vaccination programmes (Environmental Effects Panel 1994:iv).

Some plants have mechanisms to ameliorate the effects of increased UV-B radiation and may acclimate to increased levels. However, physiological and developmental processes of others are adversely affected by UV-B. In agriculture this will necessitate the selection or breeding of more UV-tolerant cultivars. The Panel reports that secondary effects in plants, such as changes in form or timing of developmental phases, may be as important as the direct effects of UV-B. Exact changes at the ecosystem level cannot be easily predicted but they will nevertheless be significant (Environmental Effects Panel 1994:v).

Globally, more than 30% of the animal protein used as human food comes from the sea. In developing countries the percentage is significantly higher. UV radiation has been shown to cause damage to early developmental stages of fish, shrimp and other sea organisms, and even small increases in UV could result in significant reductions in certain fish populations (Environmental Effects Panel 1994:4-2).

Increased UV radiation could reduce the productivity of both marine and terrestrial ecosystems, thereby reducing the uptake of atmospheric carbon dioxide. The Panel notes that this could alter the sources and sinks of greenhouse gases and important trace gases such as carbon dioxide, carbon monoxide and carbonyl sulphide (Environmental Effects Panel 1994:vi).

Additional UV-B results in increased production and destruction of polluting gases such as ground level ozone and hydrogen peroxide, which are known to have adverse effects on human health, plants and outdoor materials. The Panel reports that tropospheric (ground-level) ozone is expected to increase in polluted regions, with high nitrous oxides reaching potentially harmful concentrations earlier in the day. Some plastics and other materials of commercial significance are adversely affected by UV, reducing their useful outdoor life. This will add to the cost of using or maintaining these outdoor materials in the future (Environmental Effects Panel 1994:vii-ix).

The Panel noted that many of the changes induced by increased UV radiation will be so complex that it is not possible to quantify them. The Panel concluded that the increases in UV-B radiation already observed, and those expected in the future will have significant consequences in even the most favorable scenario of ozone depletion, so it strongly endorsed continued efforts to protect the ozone layer (Environmental Effects Panel 1994:ix).

2.3. International Controls on Methyl Bromide

At the international level, the Copenhagen Amendments to the Montreal Protocol froze the consumption of MB at 1991 levels in industrialised countries, starting in 1995. An exemption was made for quarantine and pre-shipment uses. The parties also adopted a non-binding resolution urging nations to make every effort to reduce MB emissions, and to discuss an appropriate control scheme at the Montreal Protocol meeting in 1995.

At the Montreal Protocol meeting in Bangkok 1993, seventeen countries signed a voluntary Declaration, stating their determination to:

- reduce consumption of MB by at least 25% by the year 2000 at the latest; and
- totally phase out the consumption of MB as soon as technically possible.

The signatory countries were Zimbabwe, Botswana, Austria, Belgium, Canada, Denmark, Finland, Germany, Iceland, Israel, Italy, Liechtenstein, Netherlands, Sweden, Switzerland, United Kingdom, and the United States.

The Montreal Protocol meeting in Vienna 1995 agreed that industrialised countries would:

- reduce MB production and consumption 25% by the year 2001, and 50% by 2005; and

- phase out MB production and consumption by 2010 (up to 15% of the 1991 production level can continue in order to supply developing countries) (UNEP 1995:Annex III).

Quarantine and pre-shipment uses, comprising approximately 17% of world use, were exempted from these controls. However, all countries were urged to refrain from using MB wherever possible (UNEP 1995:Decision VII/5). Governments may decide to permit some quantity of MB for "critical agricultural uses" beyond the phase-out (UNEP 1995:61). The Technology and Economic Assessment Panel (TEAP) was asked to examine the need for "critical agricultural use" exemptions, and possible procedures and criteria (UNEP 1995:Decision VII/29). This issue will be discussed at the Montreal Protocol meeting in 1996.

Recognising the special needs of developing countries, the Montreal Protocol meeting agreed that by 2002 developing countries should limit consumption of MB to the average annual amount they used in the period 1995-98 (UNEP 1995:Annex III). Methyl bromide used for quarantine and pre-shipment is exempt.

TABLE 2.2

International controls on MB. Control schedules agreed under the Montreal Protocol.

Controls in Industrialised Countries	
Freeze at 1991 level - except for quarantine & pre-shipment uses	by 1995
25% reduction - except for quarantine & pre-shipment uses	by 2001
50% reduction - except for quarantine & pre-shipment uses	by 2005
Phase-out - except for quarantine and pre-shipment uses. - except for essential and/or critical agricultural uses	by 2010
Controls in Developing (Article 5) Countries	
Freeze at 1995-98 (annual average) level - except for quarantine & pre-shipment uses	by 2002

Source: UNEP 1995: Annex III.

Four developing countries and 17 industrialised countries signed a voluntary Declaration at the Montreal Protocol meeting in 1995, noting that faster movement towards phasing out MB would reduce the human and environmental impacts of ozone depletion (see box on page 10). They stated their determination to:

- encourage the widespread adoption of alternatives; and
- take measures to limit consumption to necessary applications only, and to phase out as soon as possible (UNEP 1995:Annex X).

The 1997 Montreal Protocol meeting will examine new technical and economic information about alternatives and will consider adjustments to the controls on MB (UNEP 1995:Decision VII/8).

VIENNA DECLARATION ON METHYL BROMIDE

Signed by Australia, Austria, Belgium, Botswana, Canada, Denmark, Finland, Germany, Iceland, Italy, Luxembourg, Malawi, Mauritius, Netherlands, New Zealand, Norway, Sweden, Switzerland, UK, USA and Venezuela, at the Montreal Protocol meeting in December 1995.

"The above Parties present at the Seventh Meeting of the Parties to the Montreal Protocol, Commend the international community for taking constructive steps in strengthening controls on methyl bromide,

Being aware that faster movement towards phasing out methyl bromide would reduce the human and environmental impacts of ozone depletion,

Being aware that some Parties are able to adopt alternatives at an earlier stage, and that several Parties have adopted domestic policies to largely phase out methyl bromide in the next few years,

Declare their firm determination, at the national level:

(a) To encourage the widespread adoption of alternatives;

(b) To take all appropriate measures to limit the consumption of methyl bromide to those applications that are strictly necessary, and to phase out the consumption of methyl bromide as soon as possible."

Source: UNEP 1995:81. The list of signatory countries was provided by the Delegation that presented the Declaration during the meeting.

2.4 National Controls on Methyl Bromide

A number of countries have agreed on legislation to phase out or reduce consumption of MB more quickly. Table 2.3 outlines national legislation and policies to reduce or end consumption of MB in advance of what is required under the Montreal Protocol. The USA, which uses more MB than any other country, has agreed to regulations to phase out production for national use by the year 2001 (USA Federal Register 1993).

Austria has made a commitment to phase out use of MB by 2000, and has recently adopted a regulation to prohibit storage uses by 1998. Denmark has introduced regulations to eliminate domestic use by 1998 and so far has achieved a substantial reduction of 64% from 33 tonnes in 1991/92 to 12 tonnes in 1994 (Danish EPA 1994 and 1995). The other Nordic countries have also agreed to phase out MB by 1998 (Nordic Environmental Strategy 1995).

Indonesia has issued a decree which schedules a phase-out for MB; registrations for MB imports expire by May 1997. Formulations containing MB cannot be kept on Indonesian territory after January 1 1998 (Menteri Pertanian 1994).

The European Union, the second largest user after the USA, has agreed to regulations that will cut MB consumption by 25% in 1998 (EC Official Journal 1994). Canada has also introduced regulations to reduce consumption by 25% in 1998 (Canada Gazette 1994).

One intensive horticultural region of Italy phased out the use of MB in the 1980s because of concerns about local water contamination (Regional Ordinance 288, August 3 1983). In June 1994, the Italian Ministry of Health issued a national Ordinance restricting fumigation of fields to one year in two (Italian Official Gazette 1994). Industry sources report that Italian sales of MB were lower in 1994 as a result (Agrow 1995:8). Italy's Chamber of Deputies and Senate passed a law in 1993 to phase out MB by 2000, with exemptions in exceptional circumstances (Law 549/92 of December 28 1993). Due to a change in policy the phase-out date has been suspended and is under review. However, Italy signed the Vienna Declaration on MB in 1995, stating its firm determination to phase out as soon as possible.

Germany has eliminated the use of MB for stored grains and food crops, and the Netherlands has phased out all soil uses, because the governments were concerned about problems such as water contamination, food residues and/or safety to agricultural workers and local communities exposed to MB (Ketzis 1992, Miller 1994, Netherlands Lower House 1981).

TABLE 2.3

National legislation and policies for reducing or phasing out domestic consumption of MB in advance of international schedules.

Country	Measure and	Agreed phase-out or reductions year adopted
USA	Regulation 1993	Phase-out by 2001
Austria	Regulation 1995	Phase-out storage facility use by 1998
	Agreed policy	Phase-out other uses by 2000
Denmark	Regulation 1994	Phase-out by 1998 - Eliminate certain uses by 1995 - Phase out main use (glasshouse tomatoes) by 1996
Sweden, Norway, Finland	Nordic environmental strategy agreement	Phase-out by 1998
Indonesia	Decree 1994	Phase-out by 1998
Italy	Parliamentary law 1993 - partially suspended	Phase-out by 2000 agreed by Chamber of Deputies and Senate, but date suspended and under review
	Ordinance 1994	Fields may be fumigated only in alternate years, Limit on application dose
European Union	Regulation 1994	25% cut in 1998 - Requirement to take all precautions to prevent leakage - Regular review of permitted uses
Canada	Regulation 1994	25% cut in 1998 - Permits required to import MB for quarantine or pre-shipment uses
Germany	*	Treatments for food crops and stored grains have been phased out
Netherlands	*	All soil treatments have been phased out
Switzerland	*	Soil uses not permitted

Note: Some regulations allow exemptions for essential uses or for quarantine and pre-shipment uses.
* *Introduced because government agencies were primarily concerned about water contamination, food residues and human health.*

2.5. *Importance of Methyl Bromide in Developing Countries*

Photographer: S. Smith

Bromine processing facility of Dead Sea Bromine in Israel, where bromine extracted from the Dead Sea is used to manufacture methyl bromide and other chemical products, primarily for export.

Developing countries use about 18% of the MB manufactured globally (MBTOC 1994:7). Although this is a small proportion of the global total, it is a significant amount (about 14,500 tonnes) (TEAP 1995:67). Several Article 5 countries have become dependent on the use of MB for important aspects of their economies (MBTOC 1994:285).

Export crops grown with the assistance of MB include tobacco, cut flowers, strawberries and vegetables. These crops generate foreign currency revenues. Cut flowers from Kenya, for example, account for 13% of the foreign exchange earnings. In Zimbabwe, MB is used for about 98% of the area of tobacco seedbeds, and tobacco exports account for 20-25% of the country's export earnings. A significant proportion of soil used to produce horticultural exports is treated with MB in Zimbabwe, where the exports were worth about US$27 million in 1994. The sector is also a major source of employment (Standard Chartered Bank 1995).

Grain stocks are sometimes treated with MB to inhibit pests. In some regions, it has become an important technique, contributing to food security. MB is currently the cheapest technique in Zimbabwe for conserving grain stock. It was especially important during the 1992 drought in southern Africa when large quantities of maize had to be moved rapidly into the region. The fumigant was used to prevent transfer of the Larger Grain Borer (*Prostephanus truncatus*), a very damaging pest.

Quarantine and pre-shipment treatments for certain commodities are sometimes required by quarantine authorities or commercial companies. These uses are economically important to developing countries. For example, grapes exported from Chile to the USA accounted for 3% of total exports (MBTOC 1994:292).

Since developing countries are attempting to deal with poverty, global inequalities and large debt repayments, they are more aware of the need for sustainable development. The replacement of ozone-depleting substances can create additional difficulties but also offers opportunities for local economic development and job creation. The level of infrastructure - insufficient administrative, research and training capacity and difficulties in information transfer - also places constraints on the development or introduction of alternatives. These issues must be fully considered when discussing the economic implications of replacing methly bromide.

CHAPTER 3

Zimbabwe:

Methyl Bromide Use and Existing /Potential Alternatives

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THIS CHAPTER PRESENTS SURVEY INFORMATION ABOUT THE CROPS, COMMODITIES AND PESTS FOR WHICH METHYL BROMIDE (MB) IS USED, AND ESTIMATED TONNAGES. IT IDENTIFIES THE VALUE OF MAJOR SECTORS, AND THE SIZE AND PROPORTION OF AGRICULTURAL PRODUCERS USING MB AND ALSO PROVIDES AN OVERVIEW OF EXISTING AND POTENTIAL ALTERNATIVES RELEVANT TO ZIMBABWE USERS.

3.1. Survey

For the purpose of this study, surveys were carried out in Zimbabwe; a number of MB suppliers, users and relevant experts were asked for detailed information. More than 102 agricultural producers and 8 organizations were surveyed (Table 3.1) to identify treated crops, commodities and pests, and the quantities of MB used in 1994.

3.2. Overview of Uses and Users

Methyl bromide is used in Zimbabwe to kill pests in soil, stored grain and export products. Users reported that they used MB to kill about 17 insect species of concern to them, as well as to control weeds and soil phytopathogens (organisms that cause disease in plants).

The survey identified one sector that uses a large amount of MB (tobacco growers), two sectors using moderate amounts (stored grain, and horticulture), and more than four sectors using small quantities (exports of tobacco, artifacts and horticulture, and destruction of termite nests). The majority of MB is used by commercial companies and a former parastatal organization.

OVERVIEW OF SECTORS USING MB:

1) Soil treatment for tobacco seedbeds - 83% of MB use
   The tobacco sector is very important in Zimbabwe, accounting for 20% - 25% of foreign currency earnings. There are approximately 1,800 large-scale commercial tobacco farms, virtually all of which use MB. About 500 (50%) of the 1,000 small-scale tobacco growers use MB. Only a few large farms are foreign-owned.

2) **Fumigation of grains in storage and for export - 13% of MB use**
Stores of grain are important for food security. The Grain Marketing Board (GMB), a parastatal until very recently, holds the national stores and treats most types of grain with MB. It is not used by farmers for on-farm storage.

3) **Soil treatment for flowers, nurseries and seedbeds - 3% of MB use**
The horticultural sector has a high value and is very important for export earnings. A small proportion of horticultural producers use MB. Users are generally large-scale commercial farms. Most farms are Zimbabwean but some are foreign-owned (European, especially Dutch). No small-scale farmers in horticulture use MB.

4) **Fumigation of tobacco leaf exports - <1% of MB use**
A small proportion of tobacco exports (about 5%) is treated with MB, as a requirement of certain importing countries. MB is used primarily by large and very large tobacco exporters with a mix of Zimbabwean and European ownership.

5) **Fumigation of export curios and artifacts - <1% of MB use**
Use of MB for fumigation of export curios is a significant export sector. Treatments are carried out by professional fumigators.

6) **Quarantine treatment for horticultural exports - <1% of MB use**
Some cut flowers and occasionally fresh vegetables are fumigated prior to export. More often, exports are fumigated with MB on arrival in importing countries, such as Australia and Mauritius, if pests of concern are detected.

7) **Miscellaneous minor uses - <1% of MB use**
For example, killing termite nests and disinfesting sacks in coffee mills are minor uses of MB.

Although some areas use very small quantities, the use is often economically important, especially in the case of treatments for exports.

3.3. Quantities Used for Crops and Commodities

Estimates of the quantity of MB used in Zimbabwe vary. The Agricultural Chemicals Industry Association estimates that use is between 850 and 900 tonnes per year. Our survey found an estimated usage of more than 604 tonnes in 1994. This figure would normally be higher, but less MB has been used for grain stocks in recent years because of droughts.

In 1992 Zimbabwe was estimated to be the second-highest user of MB on the African continent, after Egypt (MBTOC 1994:287). A United Nations Development Programme (UNDP) survey in 1995 found that it was probably the highest user in Africa (UNDP 1995).

Among developing countries Zimbabwe ranks as one of the highest users. In 1992 it was probably the ninth highest user after Brazil and the Republic of Korea (1,400 tonnes each), Thailand (1,200 tonnes), China and Mexico (1,000 tonnes each), Jordan (900 tonnes), Turkey (800 tonnes) and Egypt (750 tonnes) (MBTOC 1994:286).

Methyl bromide is not manufactured in Zimbabwe. It is imported from two sources: Dead Sea Bromine company in Israel and Great Lakes Chemical Corporation in the USA. About 60-75% comes from Israel but the quantity varies because local importers buy on price and availability.

According to our survey results about 515 tonnes (85%) of MB were used for soil fumigation, 82 tonnes (14%) for durable commodities, and a small quantity (less than 1%) as a quarantine treatment for perishable exports in 1994. According to MBTOC estimates, developing countries on average use about 70% for soil, 20% for durables, 7% for perishables and less than 1% for structures (MBTOC 1994:289-292). The proportions used in Zimbabwe vary significantly from these average figures: the country uses a higher proportion for soil, and a slightly lower proportion for durables and perishable commodities (see Figure 3.1 and Figure 3.2).

In Zimbabwe MB is used for the production of tobacco, cut flowers and a relatively small amount of fresh fruit and vegetables. It is used for growing high-input horticultural crops which are almost entirely for export. In this respect it is like other developing countries. MBTOC reports that MB is not used to grow staple foods such as maize or wheat (MBTOC 1994:284).

In the vast majority of developing countries, MB is used by large and medium sized companies rather than small farmers. Zimbabwe is unusual in that MB is used by

TABLE 3.1

Producers, companies and organizations surveyed in Zimbabwe to identify consumption and users of MB.

Agricultural sector or organization	Number of producers or companies surveyed
Agricultural Producers	
Tobacco	10
Pea	20
Deciduous fruit	14
Paprika, capsicums	7
Asparagus	4
Roses	8
Other flowers	3
Tomatoes	2
Cole	3
Cucurbits	1
Beans	12
Baby sweetcorn	4
Nuts	1
Strawberries	3
Passion fruit	1
Tropical fruit	2
Onion	1
Nurseries	3
Animal feed producers	2
Seed producers	1
Other Organizations	
Professional fumigators	2
Government plant inspection dept	1
Horticultural Promotion Council	1
Tobacco Research Board	1
Zimbabwe Tobacco Association	1
National Museum	1
Affretair	1

FIGURE 3.1
Estimated use of MB in developing countries (MBTOC 1994).

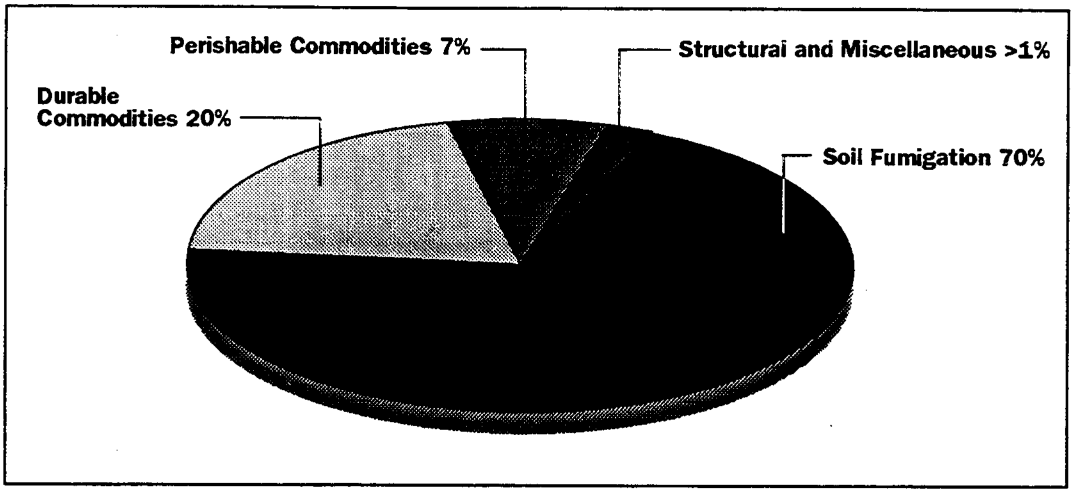
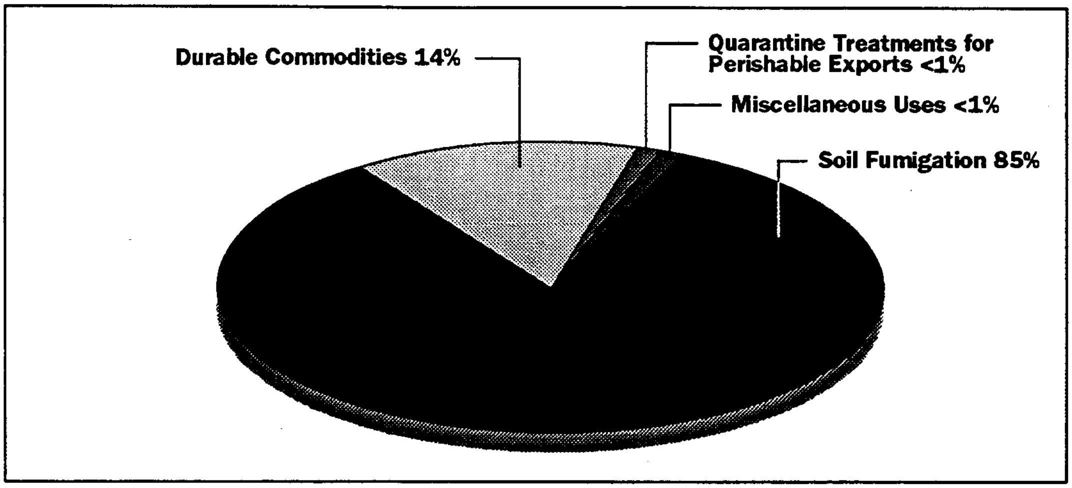


FIGURE 3.2
Major applications of MB in Zimbabwe (survey results).



about 500 small farmers for tobacco. Brazil is believed to be the only other developing country where it is used by a large number of small farmers, also for tobacco.

The estimates in Table 3.2 show the main agricultural sectors using MB. The tobacco industry uses the greatest quantity, consuming about 500 tonnes (83%) in 1994. Grain is the next most important sector, using 78 tonnes (13%) in 1994. The cut flower sector used about 12 tonnes (2%), and the rest of the horticultural sector used about 3 tonnes (<1%) for soil and post-harvest treatments.

The quantity of MB used in some sectors varies significantly from year to year, particularly for grain. For example, the GMB used 62 tonnes in 1992, 16 tonnes in 1993 and 78 tonnes in 1994 because of fluctuating amounts of grain in storage (Kutukwa & Juriangwa 1995).

TABLE 3.2

Estimated quantity of MB consumed in Zimbabwe in 1994 (survey results).

Soil and Commodity Applications	**MB used by sector (tonnes/yr)**	**MB used by crop (tonnes/yr)**	**Percent by sector**	**Percent by sector**
Tobacco Crop	*500 (sub-total)*	*83%*		
Tobacco seedbeds		500		83%
Tobacco fields/lands		0		zero
Cut Flower Crops	*12 (sub-total)*			2%
Roses		5		1%
Chrysanthemums		1		<1%
Asters		1		<1%
Other flowers		5		1%
Nurseries/Seedbeds	*3 (sub-total)*		*<1%*	
Paprika seedbeds		>1		<1%
Tomatoes		0.5		<1%
Cole		0.2		<1%
Citrus		0.3		<1%
Coffee		0.5		<1%
Other		0.5		<1%
Perishable Exports	*<5 (sub-total)*		*<1%*	
Cut flowers		small, variable amount		<1%
Fruit & veg.		small, variable amount		<1%
Durable Commodities	*82 (sub-total)*		*14%*	
Tobacco exports		3		<1%
Curios and artifacts		1		<1%
Grains		78		13%
Other Uses	*2 (sub-total)*		*<1%*	
Termite nests		0.5		<1%
Total	*604*	*604*	*100%*	*100%*

TABLE 3.3
Area of crop cultivated or tonnage exported for each main sector, and percentage treated with MB.

Sector	Total crop area or commodity tonnage	Area or tonnage treated with MB	Percentage treated with MB
Tobacco (export value: US$530 million [1])			
Seedbeds (soil)	910 ha	880 ha	98%
Tobacco (post-harvest)	169,220 tonnes	10,000 tonnes	5%
Horticulture (export value: US$62 million [2])			
Roses (soil)	200 ha	10 ha	5%
Other cut flowers (soil)	520 ha	13 ha	3%
Strawberries (soil)	25 ha	0 ha	zero
Nurseries (soil)	c.25 ha	3.6 ha	c.20%
Cut flowers (post-harvest)	8,000 tonnes	small quantity	n/a
Fruit & veg. (post-harvest)	6,400 tonnes	small quantity	n/a
Grain			
Storage, export, import (post-harvest)	1,295,000 tonnes	large quantity	high percentage

[1] *Estimated value of 1994/95 crop (Blair 1995b).*
[2] *Value of exported flowers, vegetables and fruit including citrus, in 1994/95 season.*

3.4. Significance of Methyl Bromide in Main Sectors

3.4.1. Tobacco Sector

About 98% of the tobacco grown in Zimbabwe is exported. The value of the 1994/95 crop is expected to be US$532 million, amounting to about 20% to 25% of Zimbabwe's foreign exchange earnings (Blair 1995b). The sector is also a major source of employment (Standard Chartered Bank 1995), with about 6% of the population of Zimbabwe dependent on the tobacco industry (Blair 1995b).

Methyl bromide is used to treat about 98% of the area of tobacco seedbeds (table 3.3). About 500 tonnes of MB were used in 1994. Typically about 550 tonnes per year is used (Blair 1995b). Methyl bromide is not used to treat the soil for growing mature tobacco plants (tobacco lands) due to relatively slow application, high cost of sheeting and tape, and the impracticality of moving sheets over large areas.

There are approximately 1,800 large-scale tobacco growers, virtually all of whom use MB. About 500 of the 1,000 small-scale growers use MB. In total, about 2,300 tobacco growers (82%) use MB.

There are 910 hectares of tobacco seedbeds grown in Zimbabwe; the vast majority grown by large-scale commercial growers. About 20 hectares (2%) of the seedbeds are for Virginia tobacco grown by small-scale farmers covering about 1,500 hectares. Small-scale farmers growing Burley tobacco (covering 2,000 hectares) do not use MB.

About 15% of the large-scale commercial farms are foreign-owned, and the rest Zimbabwean. Each are several hundred hectares in size, grow crops other than horticultural crops, and most keep livestock. They grow 40 to 75 hectares of tobacco on average, although some grow 150 to 200 hectares. These large farms have management personnel trained to college or often university level, who are technically the most skilled farmers in Zimbabwe. The large farms have relatively good financial security and access to loans. A Tobacco Research Board (largely financed by farmers paying a levy on tobacco sales) provides good technical support to growers.

The tobacco is exported to about 120 countries in Western Europe (51%), Asia (21%), Eastern Europe (11%), North America (9%), and the Middle East (8%).

In 1994 about 3.2 tonnes of MB were used to fumigate 10,000 tonnes of tobacco prior to export. This amounted to about 5% of tobacco exports (Table 3.3). The MB was applied to meet the quarantine requirements of a small number of importing countries, principally Japan and Taiwan. Tobacco exporters either own fumigation chambers or apply fumigants under sheeting. Fumigations may be carried out by their own staff or by contract fumigators.

Phosphine has largely replaced MB as a fumigant, and was used for about 95% of tobacco exports in 1994. Fumigation prior to shipment is not required by most importing countries, but as a precaution, almost all tobacco is treated in Zimbabwe because it is more expensive (financially and for the producers reputation) if tobacco beetle is found by the importing country.

3.4.2. Grain Sector

Methyl bromide is used for grain only by the Grain Marketing Board (GMB). It is not used by farmers for on-farm grain storage, nor by grain millers or animal feed manufacturers.

The GMB holds national grain stocks and is the main grain marketing authority in Zimbabwe. Its role has recently been changed to make it more market-oriented. It has an extensive network of large storage areas and treatment depots throughout the country and plays an important role in food security in the region. Grains are mainly consumed locally. Grain is exported when sufficient quantity is produced, and imported when the crop grown in Zimbabwe does not meet national demand.


Photographer: Melanie Miller

Sacks of grain at a national grain store in Kenya being prepared for fumigation with methyl bromide. The methyl bromide cylinder sits on a weighing device for measuring the correct dose; pipes carry the gas to the top of the stack.

Since it was first established the GMB predominantly used MB for pest control and is technically skilled in applying it. Grain in storage may be fumigated two or three times a year, sometimes with phosphine and it may be stored for up to three years before marketing, depending on the quantity harvested and demand for grain.

The GMB used 78 tonnes of MB in 1994, accounting for about 13% of Zimbabwe's use. Drought and other factors have led to low use of MB. In normal years up to 250 tonnes might be used. The GMB expects to use up to 200 tonnes in 1995.

GMB's capacity for grain storage is 5 million tonnes: about 20% in bulk and 80% in bags. In a normal year there would be 2 million tonnes of maize and 0.5 million tonnes of other cereals. This would require 100-250 tonnes of MB, depending on the level of pests. Normally about 80% would be used for maize and about 20% for wheat. A very small amount of MB is used for rice because it is imported in response to demand, not held in stock, and a small quantity of MB is used to treat empty grain sacks.

The GMB fumigates cereals in stacks but not in bulk storage. Oilseeds are not fumigated with MB. Phosphine is used for bulk storage, legumes, sorghum and finger millet *(Eleusine coracana)*.

Grain for export often is required to be fumigated prior to shipment. The Middle East requires fumigation but does not specify which fumigant, while Japan specifies that MB must be used. Grain imported into Zimbabwe must be fumigated, but the fumigant is not specified.

3.4.3. Horticultural Sector

Export earnings from horticultural exports (cut flowers, vegetables, fruit and citrus) were US$62 million for the 1994/95 season, exceeding both the value and volume of previous years. Flowers accounted for 58%, vegetables and non-citrus fruit for 30%, and citrus for 12% of the value (The Herald 1995). Horticultural output is expected to continue to grow.

In 1994/95 8,000 tonnes of **cut flowers** were exported, earning US$36 million. This represented growth of 49% on the 1992/93 figures according to the Horticultural Promotion Council. In 1992/93, 5,216 tonnes of cut flowers were exported.

The flower production area on individual farms seldom exceeds 10 hectares. The farms themselves are mostly large scale operations of which the flowers are one small part. The sector employs on average 25 people per hectare (The Herald 1995).

Our survey found that about 23 hectares (3%) out of 720 hectares of flowers are treated with MB (Table 3.3). Approximately 12 tonnes of MB were used in 1994. Roses accounted for 5 tonnes (42%) of this, chrysanthemums and asters accounted for 2 tonnes, and the rest is used for a wide variety of other flowers (Table 3.2).

Vegetable and fruit exports (excluding citrus) earned US$18.5 million in 1994/95. This represented an increase of 20% from the previous year. Areas producing horticultural crops in Zimbabwe are relatively small and are often part of much larger mixed farming enterprises. Less than 1 tonne of MB was used in 1994. Small-scale horticultural producers do not use MB.

Citrus exports earned about US$7 million in 1994/95. The area planted with citrus has expanded rapidly and now covers about 4,000 hectares. About 0.3 tonnes of MB was used for citrus in nurseries in 1994.

In the last few years use of MB has increased rapidly for **paprika seedbeds**, an important export crop primarily used for paprika oleoresin, a colorant for food, drugs and cosmetics.

Nurseries used about 2 tonnes of MB in total in 1994. The nurseries grow a wide range of plants, primarily tomatoes, cole (eg. cabbage), as well as citrus (Table 3.2). There are relatively few commercial horticultural nurseries in Zimbabwe and they are small, Zimbabwean-owned, and usually independent of large-scale farms.

Photographer: Melanie Miller

Preparation for methyl bromide strip fumigation in Zimbabwe's horticultural sector.

Coffee nurseries, in contrast, are on large commercial coffee estates, mostly Zimbabwean-owned. About 0.5 tonnes of MB was used in nurseries for coffee (which is not classed as a horticultural crop). Small-scale coffee producers do not use MB. Coffee is not treated with MB after harvesting, although coffee mills sometimes fumigate sacks.

Photo: Melanie Miller

"Hot gas" method of soil fumigation, a technique used in Zimbabwe's horticultural sector. Methyl bromide is piped via a drum of hot water so it is converted to vapour before being applied to the soil.

Technical resources in horticulture and coffee production are fewer than in the tobacco sector. Farmers are skilled but there are limited research facilities. Limited technical assistance is provided by the Horticultural Research Station and the Coffee Research Station. Foreign and local consultants play a large role in technology transfer in this sector and often recommend use of MB.

Horticultural products and propagules imported into Zimbabwe are not fumigated with MB because it often harms the plant material.

Most cut flowers are exported to Europe. South Africa is reported to be the second largest importer, followed by Australia, the USA and Mauritius (Roozendaal 1994:7). Vegetables and fruit are exported mainly to Europe but also to South Africa, Asia and Australia. In a small number of cases, for example certain products sea-freighted to Mauritius, products are given a quarantine treatment in Zimbabwe prior to export. More commonly, products are fumigated by the importing country if quarantine pests are detected. Australia, for example, has intercepted pests in quite a few batches of snowpeas and cut flowers airfreighted from Zimbabwe, and so has applied MB on arrival.

3.5. Trends in Consumption of Methyl Bromide

Developing countries are estimated to use approximately 18% of the MB used worldwide (MBTOC 1994:285). Worldwide, the use of MB grew at the rate of 5.5% per year between 1988 and 1992 (TEAP 1995:66). Limited data suggest much larger rates of increase in the use of MB are anticipated for Article 5 countries developing horticultural industries such as cut flowers for export (TEAP 1995:68).

Our survey of users in Zimbabwe found that use of MB is certainly rising in horticultural export sectors, while falling in other sectors. It is not possible to ascertain whether overall use will rise or fall in the next few years. One factor promoting consumption is that some consultants and chemical suppliers continue to recommend the use of MB in Zimbabwe, even in instances where alternatives could be used.

Use of MB for paprika seedbeds is likely to continue increasing as production increases. Use for citrus is likely to increase from the small current level, because the area of citrus planting has been expanding rapidly. Other horticultural crops are due to expand, and in some cases this would increase use of MB.

However, use of MB for strawberries has virtually ceased. A major strawberry producer stopped using MB a number of years ago, and continues to use alternative methods. Hortico, a large horticultural exporter also growing strawberries, tested alternatives for the 1993 visit of the MBTOC committee. On finding that MB made no detectable difference to productivity, they stopped using it. Apparently one grower working with Hortico has started to use it again because it is a familiar product, but the other growers are still using the alternatives.

Use of MB for grain stocks has dropped in recent years because of drought. Large stockpiles of grain are no longer deemed necessary, in part because the GMB has moved into a market oriented situation where it can trade freely. This suggests that use of MB would remain low for this sector.

However, the GMB tendered for and has taken delivery of 200 tonnes of MB for 1995, so the proportion of stocks treated with MB (compared to phosphine) is likely to rise in 1995.

Use of MB as a pre-shipment fumigant for tobacco has declined substantially in recent years. This is mainly because it can cause methylation, decreasing tobacco leaf quality. Some European tobacco importers now insist that MB must not be used, due to environmental concerns.

Companies in Japan and Taiwan actively require pre-shipment fumigation with MB for commodities such as tobacco. If exports to these countries increase then use of MB will increase in parallel, unless the importing countries or companies change their policies to accept substitute quarantine or phytosanitary treatments.

Use of MB for flower and snowpea exports to Australia is likely to increase this year because of pest control problems. Methyl bromide may be applied to new uses in future, such as apple imports from South Africa.

3.6. Alternative Methods of Soil Pest Control

3.6.1. Alternatives for Tobacco Seedbeds

Methyl bromide is used extensively on tobacco seedbeds in Zimbabwe because it is very effective in controlling broad-leaved weeds, grass weeds, nematodes, soil insects and soil fungi including one causing anthracnose (*Colletotrichum tabacum)* (Table 3.4). The farmers are accustomed to using MB and have a great deal of confidence in its ability to perform well.

The Zimbabwe Tobacco Research Board (TRB) has undertaken research on some potential alternatives, and has recommended several other fumigants (Shepherd 1993, Blair 1995b). For example, a mixture of 1,3-dichloropropene (1,3-D) and methyl isothiocyanate (MITC) gives good control of nematodes, controls some soil insects and soil fungi, and greatly reduces the number of broadleaved weeds and grasses. Selected techniques could be used to control other soil insects and weeds. However, 1,3-D and MITC are more expensive and like MB, these fumigants are toxic and may cause environmental contamination. Therefore, they have significant drawbacks compared to non-chemical alternatives.

The TRB and farmers have found that dazomet, metam-sodium and 1,3-D mixed with MITC are not as effective or reliable as MB. But the full range of pests can be controlled. The results are likely to improve with further knowledge (Shepherd 1993, Blair 1995b).

A treatment that the TRB found to give excellent results also poses human safety problems. The treatment combines ethylene dibromide (EDB) (which is no longer permitted in some countries (MBTOC 1994:80)) to control nematodes and soil insects, with the burning of brushwood or maize cobs on the seedbed area to destroy weed seeds (Shepherd 1993:2). The Board does not recommend this practice because burning brushwood would lead to further deforestation, carbon dioxide and smoke pollution (Blair 1995b). Burning vegetation would also generate very small amounts of MB (WMO 1994).

The TRB has recommended several Integrated Pest Management (IPM) techniques. It recommends that seedbed sites are rotated and that a specific cover grass crop (a non-host to nematodes) is planted in the rotation. These can contribute to the weed seed problem (normally killed by MB) and it would be useful if a hybrid sterile grass could be developed. Nematode-resistant tobacco cultivars have been commercialised and are more tolerant of nematodes. Greater use of tobacco cultivars resistant to *Meloidogyne javanica* would lessen the necessity for perfect control of nematodes (Shepherd 1993:2). The problems of disease, weeds and insects would have to be addressed by other techniques.

The biological control agent *Trichoderma harzianum* helps to control sore-shin complex. A study by the Philippines National Tobacco Administration Research and Training Center found that *Trichoderma harzianum* effectively controlled the two most destructive fungi affecting tobacco in the area *(Sclerotium rolfsii* and *Pythium apanidermatum). Trichoderma* was developed by the TRB for use in Zimbabwe and is sold as a commercial pest control product.

The TRB is investigating techniques such as soil substitutes, seed trays (conventional and floating), permanent seedbed sites, as well as a combination of dazomet and EDB (Blair 1995b). TRB has found that doses of MB could be reduced by 50% (from 50 g/m^2 to 25 g/m^2), providing sheets are gas-tight (Blair 1995b). If doses were halved in the entire sector, consumption of MB could be reduced by approximately 250 tonnes per year.

The TRB concluded in 1993 that though withdrawal of MB would be very disruptive, they would be able to overcome the problems (Shepherd 1993:2). After further research in 1995 the TRB stated that if MB were to be banned "a number of alternatives are either available or could possibly be implemented after further development work" (Blair 1995b:1).

The spectrum of pest problems can be controlled by selecting an appropriate technique for each pest, or by creating a sterile seedbed using steam or clean substrates. At present there are few reliable nematode testing facilities in Zimbabwe. The establishment of more facilities in Zimbabwe to rapidly test soil for damaging pests and beneficial organisms would help growers to select a nematode-free site or to be much more selective in their use of soil treatments and procedures.

It would be desirable for the sector to adopt several different alternatives, to cater to the needs of different users, for the large area, and to reduce dependence on any one technique. The most promising alternatives for Zimbabwe tobacco growers are likely to be as follows.

3.6.1.1. Seed Trays

Seedlings planted in sterile media in trays comprising separate cells are currently available for certain crops in Zimbabwe. They are produced by commercial nurseries, but farmers could grow the seedlings themselves.

The major impediment for tobacco is that it has very small seeds, making it hard to plant in trays without sophisticated equipment or pelleted seeds. However, the preparation of the seedling trays and sowing could be done by commercial nurseries. The farmer could then purchase dry, pre-sown seed trays, and irrigate and germinate them on-farm. They could potentially be floated on troughs of nutrient solution as done in other countries, although this requires careful control. Alternatively, conventional methods of irrigation and nutrition could be investigated to see if they would work adequately.

One farmer who has tried using tobacco seedlings grown in trays by a commercial nursery was interviewed for this study. He found that there was a cost involved in transporting seedlings to his farm and that they were more uneven than the seedlings he grew himself. However, the final tobacco crop was the same as tobacco treated with MB. Use of seed trays for tobacco appears to be unusual in Zimbabwe but apparently it is used more commonly in South Africa and some other regions.

3.6.1.2. Substrates in Fixed Beds

It would be feasible to construct permanent seedbeds of concrete or brick, with sides projecting well above the surrounding soil to prevent contamination. Pinebark is currently used as a growing medium in Zimbabwe. Tobacco seedbeds cover a large area, and the supply of pine bark is limited, so additional sources of substrates would need to be developed. Possibilities include selected clean waste materials, such as fresh grain hulls, grit, paper waste, composted crop residues (excluding tobacco residues), or other agricultural or processing waste. Research would be able to determine the best local materials to use as soil substitutes. To minimise environmental impacts, local, renewable sources of materials should be given preference over imported or non-renewable resources. Where necessary, sterilisation of soil substitutes at the farm level would be feasible because tobacco farms invariably have boilers to generate steam for conditioning cured tobacco.

The effective introduction of soil substitutes on a large scale would require resources for local research, farmer education and some major infrastructural changes for transporting substrates locally. It would require changes in practices and approaches.

3.6.1.3. Steam Treatments

Some tobacco growers would be able to sterilise soil or substrates with steam, where steam from conditioning boilers can be piped to the seedbeds. Steaming is used in nurseries in many countries, including Zimbabwe. Newer techniques are much more energy efficient and effective than some older steam techniques.

3.6.1.4. IPM Techniques for Tobacco

Suitable combinations of IPM techniques could be developed to suit the needs of different types of tobacco producers (table 3.4). For example, in some cases nematodes could be avoided using rotation, cover crops and nematode-resistant cultivars; and diseases could be controlled chemically. It may be possible to pre-irrigate the seedbeds and germinate the weed seeds before the long, dry winter. The weed seeds could then be allowed to die of drought or killed chemically. It would be helpful to devise a mechanism to help prevent more weed seeds blowing in (this is also a problem when using MB).

The TRB has already achieved significant progress in developing certain biological controls and plant breeding. Considerable further developments in IPM and non-chemical techniques could be made if the TRB had better funds. One organic farmer has paid for a researcher to be based at TRB to work on the control of nematodes using an actinomycete, *Pasteuria penetrans*. Seconding or sponsoring further specialists in IPM to work with the TRB experts on alternatives to MB is likely to help substantially in its replacement.

3.6.2. Alternatives for Cut Flowers and Nurseries

In Zimbabwe the flower crop pests controlled by MB are plant parasitic nematodes, weed seeds, soilborne pathogens, and soil insects. In the case of roses there is also rose replant sickness (non specific allelopathy) (see Table 3.5).

Recent research in Kenya has found that a plant extract from *Tagetes minuta* (Khaki weed) is reported to control Root Knot nematodes in rose beds as effectively as conventional nematicides (such as fenamiphos) (Okioga 1994). Some farm trials with *Tagetes* have been carried out in Zimbabwe and are continuing.

Table 3.5 lists alternative techniques for cut flower pests. A combination of appropriate techniques could be used to replace methyl bromide. Soilborne pathogens, for example, could be controlled by a fungicide drench. Nematodes could be controlled with available nematicides or potentially with *Tagetes* plant extract. If more facilities for diagnosis were established, it would be feasible for farmers to have soil tested for soilborne pathogens and soil insects to save unnecessary expenditure on drenches or other treatments. One area where a pest control technique is not currently available is for rose replant sickness. The addition of organic matter to the soil may address this problem.

Some significant flower-producing regions of the world predominantly use alternatives to MB. Colombia, for example, is the world's second-largest exporter of cut flowers. Flower cultivation covered 4,200 hectares and had a value of about US$380 million in 1993 (Van Wijk 1994:4). Methyl bromide is no longer used in Colombian flower production, except in a few isolated cases. A sophisticated system of IPM, composting and steam treatments is used very successfully (Rodriguez-Kabana & Martinez-Ochoa 1995) (see Chapter 6 for more information).

Table 3.6 shows the nursery pests currently controlled by MB, and alternative techniques. Only one nursery in the greater Harare area of Zimbabwe still uses MB. Most nurseries have already moved away from MB, commonly using steam instead.

TABLE 3.4
Tobacco seedbeds: pests controlled by MB in Zimbabwe, and potential alternative pest control techniques.

Pests controlled by MB	Alternative treatments or practices
Plant parasitic nematodes (mainly Meloidogyne javanica, M. incognita)	1. Establishing nematode testing facilities to determine whether soil treatment is necessary 2. Rotating area used as seedbed to reduce nematode levels 3. Using soil substitutes in permanent seedbeds or seed trays 4. Using steam treatments for soil or substrates 5. Using cultivars resistant to nematodes 6. Using nematicides eg. ethoprophos, fenamiphos, oxamyl, terbufos, or 1,3-D with MITC
Soil insects (eg. whitegrubs, false wireworms, cutworms)	1. Using soil substitutes in permanent seedbeds or seed trays 2. Using a steam treatment, for soil or substrates 3. Acephate, methamidophos and monocrotophos are registered for seedbed insect control 4. Some beetle and moth larvae can be controlled by fungal and bacterial pathogens, and entomophilic nematodes 5. Some insects are controlled by 1,3-D with MITC
Certain soilborne fungi (including those causing tobacco anthracnose Colletotrichum tabacum, and the soreshin complex - Fusarium solani and Rhizoctonneia solani)	1. Using soil substitutes 2. Using steam treatments 3. Thiram, mancozeb and anilazine are registered for controlling Anthracnose 4. Triadimenol, benodanil and benomyl are used against sore-shin 5. Some are controlled by 1,3-D with MITC 6. *Trichoderma*, a commercial biological control agent, can out-compete sore-shin when it can be established in the seedbed
Most weed seeds. Grass weeds predominate.	1. Pre-irrigation to germinate weed seeds, followed by dessication or herbicide or ammonium nitrate fertilizer (6-10 g/m^2) before sowing 2. Using soil substitutes 3. Using steam treatments 4. Grass herbicides eg. fluazifop-p-butyl 5. 1,3-D with MITC reduces broadleaved weeds and grasses 6. Potential development of a sterile grass (to reduce nematodes also)

TABLE 3.5

Cut flower cultivation: pests currently controlled by MB and alternative treatments for pest control.

Pests controlled by MB and procedures	Alternative treatments and procedures
Plant parasitic nematodes	1. System of composting, IPM and steam similar to system is used by cut flower industry in Colombia 2. Nematicides eg. fenamiphos, oxamyl 3. *Tagetes minuta* plant extract for Root Knot nematodes
Soilborne pathogens	1. System of composting, IPM and steam 2. Diagnosis to see whether treatment is required 3. Specific fungicide drench
Soil insects	1. System of composting, IPM and steam 2. Diagnosis to see whether treatment is required 3. Specific insecticide drench 4. Some beetles and moth larvae may be controlled by fungal and bacterial pathogens and entomophilic nematodes
Weed seeds	1. System of composting, IPM and steam 2. Irrigate seedbed to germinate weeds before dry winter period 3. Herbicides
Rose replant sickness (non-specific allelopathy)	1. System of composting, IPM and steam 2. Increasing the organic matter is effective in practice

TABLE 3.6

Nurseries: pests currently controlled by MB and alternative treatments for pest control.

Pests controlled by MB	Alternative treatments or procedures
Plant parasitic nematodes	1. Steam 2. Soil substitutes, eg. pine bark 3. Nematicides eg. fenamiphos, oxamyl 4. *Tagetes minuta* plant extract for Root Knot nematodes
Soilborne pathogens	1. Steam 2. Fungicide drenches
Soil insects	1. Steam 2. Soil substitutes 3. Insecticide drench
Weed seeds	1. Hand cultivation 2. Soil substitutes

TABLE 3.7
Cut flower exports: quarantine pests controlled by MB, and potential alternatives.

Quarantine pests controlled by MB	Potential alternatives
Thrips, including western flower thrips (Frankliniella occidentalis)	1. Improved pest control at field level followed by selected post-harvest insecticides with improved delivery systems (eg. very fine aerosols) or repeat treatments 2. Improved pest control in field followed by controlled atmosphere treatment during transit, or a combination of other suitable post-harvest treatments (Table 6.9)
Helicoverpa boll worm	1. Improved pest control at field level followed by selected post-harvest insecticides with improved delivery system, or after applying compound to draw caterpillars from crevices 2. Improved pest control in field followed by suitable combined post-harvest treatments (Table 6.9)
Spider mite	1. Improved pest control at field level followed by appropriate post-harvest miticides 2. Post-harvest chemical agitants or adjuvants eg. organo-silicone dip
Other pests	1. Chemical dips 2. For snails and large scale insects: hand removal 3. For surface pests: high pressure water spray (for robust flowers or foliage) 4. For heat sensitive pests: warm water or hot air (for robust flowers or foliage)

TABLE 3.8
Tobacco exports: pests controlled by MB, and alternative treatments.

Pests controlled by MB	Alternative treatments or procedures
Tobacco Beetle (Lasioderma serricorne) *Tobacco moth (Ephestia elutella)*	1. Pre-shipment inspection and certification 2. Phosphine 3. Carbon dioxide treatment 4. Methoprene insect growth regulator for stored tobacco 5. Potential heat treatment

TABLE 3.9
Grain exports: pests controlled by MB, and alternative disinfestation treatments.

Pests controlled by MB	Alternative disinfestation treatments
Oryzaephilus surinamensis, Rhizopertha dominica, Tribolium spp. etc.	1. Phosphine used under well-sealed conditions 2. Nitrogen controlled atmosphere treatment 3. In-transit carbon dioxide treatment 4. Potential heat treatment for rice and wheat for breadmaking 5. Dichlorvos
Larger grain borer	No alternatives approved for quarantine currently, potential alternatives as above

TABLE 3.10
Artifacts and curios: pests controlled by MB, and alternative disinfestation treatments.

Pests controlled by MB	**Alternative disinfestation treatments**
Atropos spp.	1. Heat treatment with constant controlled humidity 2. Nitrogen flow fumigation 3. Carbon dioxide treatment in some cases 4. Phosphine for artifacts free from metals or pigments

TABLE 3.11
Stored grains: pests controlled by MB, and alternative methods of pest control.

Pests controlled by MB	**Alternative treatments or procedures**
Tribolium spp. *Thizopertha dominica,* *Oryzaephilus surinamensis,* *Ephestia spp.* *Plodia, etc.*	1. Procedures to prevent infestation 2. Phosphine used under well-sealed conditions 3. Carbon dioxide treatment 4. Nitrogen controlled atmosphere 5. Insecticide eg. dichlorvos 6. Potential for hermetically sealed storage, assisted by other treatment 7. Heat treatment for rice and wheat for breadmaking 8. Inert dusts (provided conditions are sufficiently dry) 9. Grain protectants and insect growth regulators

3.7. *Alternative Quarantine Techniques*

Methyl bromide is not normally required by the Zimbabwean authorities for imported goods. Other fumigants or inspection are generally used instead.

Zimbabwe horticultural exports do not normally have to be fumigated prior to export, but if pests are detected on arrival in certain countries (such as Australia or Mauritius) the products are fumigated with MB. To replace this use of MB it would be necessary to introduce changes in procedures or new treatments in Zimbabwe prior to export.

In a small number of cases commodities are required to be treated with MB prior to export. Companies in Japan and Taiwan require tobacco and grain imports to be fumigated with MB. Fresh produce from Zimbabwe currently is not exported to these countries because the quarantine and pre-shipment requirements would be very stringent. Some of the alternatives identified in this section and Chapter 6 could be applied to provide quarantine security for Japan and Taiwan. However, quarantine treatments generally have to be agreed on a case-by-case basis, and negotiations can be extremely slow.

3.7.1. QUARANTINE TREATMENTS FOR CUT FLOWERS

Methyl bromide is toxic to many plants, and may damage cut flowers, reducing their quality and price. Therefore, pre-shipment inspection and certification is commonly used in place of MB for surface pests. Table 6.9 in Chapter 6 shows examples of other alternatives that have been approved for certain pests and flowers. For example, the USA accepts removal of the pests by hand or by pressurised water spray as a combination treatment (with insecticide dips) for certain pests. Physical removal of surface pests offers a non-toxic treatment that would be viable for some flowers, if used in combination with another technique. An aerosol of permethrin and pyrethrum insecticide is used for cut flower exports from New Zealand to Japan, but is suitable only for surface pests. Heat treatments and water jets are suitable for robust plants such as sturdy decorative foliage.

Table 3.7 lists the pests of concern in cut flower exports from Zimbabwe and identifies potential quarantine procedures and treatments that could be developed to replace MB. The suitability of treatments is determined by factors such as whether the pest is on the surface or buried in plant crevices, and the robustness of the plant.

Zimbabwe flower exporters have a particular problem with the western flower thrips, which is not fully controlled by current treatments including MB fumigation. The thrips embed their eggs in plant tissue or hide in flower buds. A field and post-harvest systems approach offers the best means of control. Thrips numbers could be reduced in the field by regular monitoring and treatment with insecticides. (Monitoring and rotation of at least 3 insecticides is essential to cope with resistance problems.) There are several potential post-harvest treatments: insecticides with improved delivery systems, or with a time period between dippings or treatments; an in-transit controlled atmosphere treatment (high carbon dioxide and low oxygen) suitable for transporting flowers by sea; and a very fine, penetrating aerosol based on several insecticides. Research would be required to develop and demonstrate the efficacy and suitability of such treatments for the pest and the commodity.

In the case of Japan and Taiwan, which specify the use of MB, there are likely to be considerable delays and difficulties in negotiating approval for an alternative with the quarantine authorities of the importing country. In contrast, Australian authorities state that they would generally require only a sound scientific paper demonstrating efficacy (AQIS 1995).

3.7.2. Quarantine Alternatives for Tobacco

The majority of tobacco is no longer treated with MB. Our survey found that only two traders used it in 1994, on request of the importing country. A small number of importing countries, principally Japan and Taiwan, require MB treatment. Most other countries accept treatment with phosphine.

Phosphine is a longer treatment, taking 7-10 days, compared to 3 days for MB at normal pressure. However, MB can cause methylation, decreasing the quality of tobacco leaf, so there is a commercial preference for phosphine. Some European importers now insist that MB not be used because of environmental concerns.

Table 3.8 shows the main pests currently controlled by MB in tobacco exports and the technically feasible alternatives.

3.7.3. Quarantine Alternatives for Grain

The GMB sometimes has to treat exported and imported grain with MB as a quarantine measure. The situation with grain exports is similar to tobacco, in that Japan and Taiwan appear to be the main countries requiring MB. Some other countries accept alternatives such as phosphine for almost all quarantine grain pests, with the exception of the Khapra beetle.

One drawback is that phosphine is more expensive than MB in Zimbabwe (although in many other countries it is often cheaper). It requires a longer treatment time and more fumigation sheets would need to be purchased. Additional demurrage charges would also need to be paid at ports.

Table 3.9 shows the alternative quarantine treatments that could be used for grain exports.

3.7.4. Quarantine Alternatives for Curios & Artifacts

Table 3.10 lists some of the potential alternatives. Phosphine is used in some countries for a diverse range of export commodities. In the Philippines, for example, it is used to treat basketwares, handicrafts, accessories, rattan furniture, and antique wooden items (UNDP 1995). It is not suitable for items containing certain metals.

Carbon dioxide treatments are used for artifacts in parts of Europe. This treatment is suitable for a wide range of items. It is a slow treatment, so would not be suitable for some exports.

In Germany, the UK and Austria a thermal technique (Thermo Lignum) is used commercially for artifacts and museum items, and is suitable for a very wide range of materials. Items are disinfested by heating up to 52°C for up to 48 hours. The moisture content of items is monitored during the entire process and kept constant to prevent damage. The process does not use toxic substances and does not cause reactions with materials.

A nitrogen flow fumigation has been developed in Germany for wood products, skins and museum items. Nitrogen is applied to items in gastight plastic bags or gastight chambers at constant low oxygen concentrations at a low pressure of 5 to 10 Pa. The treatment takes 10 to 30 or more days, depending on the pest species. This makes it suitable only for products that do not have to be exported quickly. The main advantages are that the gas does not react with the artifacts and the method is very cheap (Reichmuth et al 1993).

3.8. *Alternatives for Grain in Storage*

Grain in storage is susceptible to a variety of pests, such as *Tribolium, Sitophilus, Rhizopertha, Ephestia* and *Plodia*. It is important that grain losses are prevented as much as possible, so that food stocks are not diminished. Improvements in hygiene and hygiene training are an important first step in helping to prevent pest buildup, whatever treatment is used.

Careful examination of the traditional dosage of MB shows that reductions can sometimes be made. The GMB has found that it can reduce the MB dose from 40 g/tonnes to 30 g/tonnes for large (5,000 tonnes) well-sealed maize stacks treated outdoors (Taylor 1994).

Phosphine has replaced MB, or is used alongside it, for some types of treatment in many developing countries and is the preferred chemical where fumigation has recently been introduced (Taylor 1994). Ease of application, requiring minimal equipment with consequent lower costs, is a major reason for the popularity of phosphine. However, like MB it is a toxic gas, so there is the potential for accidents.

Insect resistance to phosphine has started to build up in certain areas where there is a lack of training or incentive among pest control personnel, or, in some cases, poor quality equipment (Taylor 1994). Improvements such as training and gas monitoring would be necessary to retain the effectiveness of the fumigant. On a technical basis alone, phosphine could probably substitute for MB in most of the current non-urgent commodity treatments in Africa and Asia (Taylor 1994). The GMB sometimes uses phosphine to fumigate grain. However, phosphine is more expensive than MB in Zimbabwe, and this is a significant barrier to greater use.

The Zimbabwe GMB is investigating other alternatives to MB. Carbon dioxide is effective where treatment does not have to be rapid. This means it is suitable for most grain in storage. It requires a high standard of gas-tightness. (Continued use of MB would require similar expenditure to improve gas-tightness.) However, retro-sealing is technically feasible. Indonesia uses carbon dioxide for treating large quantities of carry-over rice stocks stored for a year or longer. Carbon dioxide gives better grain quality than either phosphine or MB. The gas is extracted from the air so it does not add to global warming. Cement works, distilleries, smelters, cracking processes at oil refineries, and certain other industrial processes generate carbon dioxide as by-products and could potentially provide local sources in developing countries. Trials to evaluate the effectiveness of carbon dioxide in large-scale silos are in progress in East Africa (Taylor 1994). A demonstration of carbon dioxide fumigation was carried out by CSIRO, the Australian research organisation, at the GMB in 1995 (van Graver and Annis 1995).

Other controlled atmosphere techniques such as raised levels of nitrogen, also offer an effective method for controlling pests. The treatment usually kills pests over a period of weeks rather than days. The process leaves no undesirable residues, unlike MB. The main barrier is that a better standard of sealing is required (this is also the case with MB and other gases). The cost of good sealing techniques tends to be expensive at present. CSIRO has demonstrated the use of gas-tight sheeting and locally made glues in Zimbabwe (van Graver and Annis 1995).

Grain in storage does not normally have to be treated rapidly, so there are several alternatives to MB which could be adopted rapidly if financial assistance were available (Table 3.11).

3.9. Alternatives for Termite Nests

A small amount of MB is used in Zimbabwe to kill termite nests. Chemical alternatives such as fipronil can be used instead. The chemical is applied via a tube inserted into the main airshaft of the nest and sealed with wet soil. Like MB and a number of other pesticides, fipronil is capable of causing acute poisoning to operators if over-exposure occurs. Fipronil inhibits cholinesterase, an enzyme necessary for 'switching off' nerve signals after nerve impulses have been sent (Extoxnet 1993).

CHAPTER 4

Thailand:

Methyl Bromide Use and Existing /Potential Alternatives

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THIS CHAPTER PRESENTS INFORMATION ABOUT CURRENT USES OF METHYL BROMIDE (MB) IN THAILAND, ESTIMATED TONNAGES, EXPORT EARNINGS OF SECTORS USING IT, AND EXAMPLES OF EXISTING AND POTENTIAL ALTERNATIVES.

4.1. Overview of the Situation in Thailand

Thailand's economy was primarily based on agriculture until the 1960s. Since then, Thailand has experienced rapid industrialisation, accompanied by important structural transformations. The predominance of the agricultural sector has declined sharply, both in terms of contribution to GDP and in export earnings, while the manufacturing and service sectors have experienced significant growth. The manufacturing share of GDP rose from 6.8% in the past to 26.1% in the 1990s.

However, the agricultural sector remains important to Thailand in both economic and social development. Thailand is one of the major exporters of agricultural products in the world. Rice export alone ranges from 4 million to more than 6.2 million tonnes per annum, approximately 35—45% of the total world market. Export earnings from just rice and tapioca (dried cassava) products total more than US$2.5 billion.

Other exported commodities include animal feeds, pulses and oil seeds, sorghum, mung beans and cut flowers. It is anticipated that Thailand will maintain the current level of exported agricultural commodities in the future.

Methyl bromide is widely used in Thailand for the fumigation of exported commodities, grain storage, and soil. It is a cost effective and well—proven pesticide in Thailand. Alternatives must be comparable in technical, economic and practical aspects in order to be accepted.

4.2. Sources of Methyl Bromide

Methyl bromide is not manufactured in Thailand. Its importation is controlled and importers must obtain permits from the Ministry of Defense. Its usage is controlled and regulated by the Department of Agriculture, Ministry of Agriculture and Cooperatives.

The amounts of MB imported into the country from 1991—94 averaged 730 tonnes per year (Industry Department, Defense Industry and Energy Center, Ministry of Defense). Major suppliers are the USA, Israel, France and Belgium.

4.3. *Major Uses of Methyl Bromide*

The use of MB in Thailand can be categorised into three major groups:

- pest control in stored products;
- fumigation of export commodities; and
- soil fumigation.

Methyl bromide fumigation of stored products is estimated to be about 20-25% of total MB used in Thailand. The commodities in this category are mainly rice, maize, tapioca, animal feeds, mung bean and oil seeds (soya bean, groundnuts, etc.).

Fumigation of export field crops amounted to about 70% of the total MB used. Field crops that are fumigated prior to shipment are rice, maize, tapioca, pulses (white bean, red bean, mung bean) and oil crops (groundnuts, soya bean) grain sorghum, pearl barley, and sesame seeds. Exported perishables, mainly asparagus and cut flowers, that are fumigated with MB amounted to less than 1%.

Soil fumigation using MB is found mainly in the preparation of tobacco seedbeds. A lesser amount is used for golf courses, cut flower nurseries and coffee nurseries. The amount of MB used for soil purposes is estimated to be approximately 5% of the total MB used in the country (SGS 1995) (see Figure 4.1).

4.4. *Reasons for Methyl Bromide Use*

The extensive use of MB as a fumigant in Thailand can be attributed to the following:

- Methyl bromide was probably the first fumigant to be introduced and established.
- Methyl bromide has the potency required for the total eradication of insects and other pests in all stages. Its characteristics follow the rule of concentration and time product (CTP). This means that a reduction in the exposure time can be compensated for by increasing MB concentration to maintain the same effectiveness in insect control. This is a very important property of MB in situations where time is critical or expensive, such as in ships where demurrage fees are quite high.
- No insect resistance to MB has been found although it has been used in the country for a number of years.
- Several importing countries require that exported products be fumigated using MB prior to shipment, for example, Japan and Korea for fresh pineapple and Australia for grains.

4.5. When Methyl Bromide Use is Required

Importing countries often require that commodities be fumigated with MB prior to shipment. In some cases this is a requirement of the official authorities, and in others it is a commercial specification set by importing companies:

- Methyl bromide is often specified in commercial contracts or in letters of credit, so that exporters are obliged to use the fumigant.

- Commodities like grains (rice, maize, tapioca) and fruits like pineapple (exported to Japan and South Korea) are required by the quarantine authorities of the importing country to be fumigated using MB. Australia requires grains to be treated prior to shipment, because Thailand is among the countries listed as having Khapra beetle. Thai quarantine regulations do not specify fumigation with MB.

4.6. Handlers of Methyl Bromide

Four major importers of MB in Thailand control the major share of the market. Two of them are also major users, commercially involved in pest control along with approximately 20—25 registered companies. There are also companies that carry out fumigations themselves, such as in tobacco seedbed preparation.

Methyl bromide is not manufactured in Thailand and there are no reported plans to produce the gas there.

4.7. Estimates of Methyl Bromide Quantities Imported and Used

From 1991 to 1994, MB use appears to have fallen slightly, but it seems to have stabilised now (Table 4.1). It may decrease in the future because the Department of Agriculture is encouraging greater use of phosphine to replace MB where appropriate.

4.8. Estimated Amounts of Methyl Bromide Used

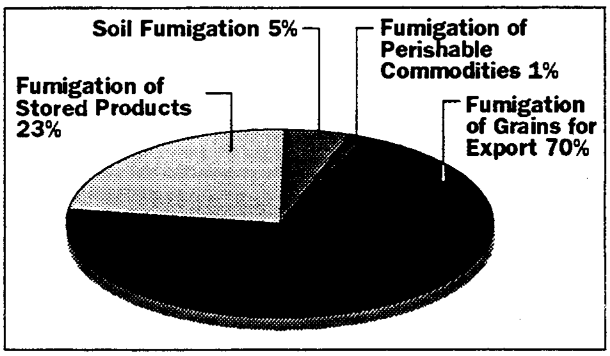
Most MB (about 70%) is used in Thailand as a treatment for grains and pulses prior to export. A significant amount (approximately 20—25%) is used for stored grains.

TABLE 4.1
Estimated MB imports and use in Thailand.

Year	MB import data (a) (tonnes)	MB use estimates (b) (tonnes)
1991	708	896
1992	658	735
1993	964	749
1994	590	617
Average	730	750

(a) Official import permit figures from the Ministry of Defense
(b) Figures from the main importing companies. There may be an additional, small amount (approximately 30 tonnes).

FIGURE 4.1
Major applications of MB in Thailand.



4.9. Crops Grown on Soil Treated with Methyl Bromide

Methyl bromide is used as a soil treatment primarily for tobacco seedbeds. Tobacco production in Thailand is highly controlled and farmers can grow tobacco only in contract farming with a licensed curing company. Seedlings are normally raised by the company and distributed to member farmers. Unofficial estimates of the amount of MB used in seedbed preparation obtained from the government's Thailand Tobacco Monopoly (TTM) for its 11 stations were 1.69, 1.20 and 1.24 tonnes for the crop years 1992/93, 1993/94 and 1994/95, respectively. Additional MB use by private tobacco companies may be a little less than the TTM's. A small amount of MB is used for golf courses, flower nurseries and coffee nurseries.

TABLE 4.3
Crops grown on soil treated with MB in Thailand.

Crops	Expected changes in the next 5 years	Probable reason(s) for the change
Tobacco seedbed	Decrease	Please see Note 1.
Golf courses	No information on trends	
Flower nurseries	No information on trends	
Coffee nurseries	No information on trends	

Note: 1. Tobacco production is a diminishing business in Thailand. The number of operational private companies have been reduced from about 10 to 3 or 4 in the past decade.

4.10. Commodities Treated with Methyl Bromide

TABLE 4.4
Commodities treated with MB in Thailand.

Commodities treated with MB	Expected changes in the next 5 years	Probable reason(s) for the change
Grains in storage		
Rice	Decrease	Note 1
Maize	No change	
Tapioca	Decrease	Note 2
Feed Grains	No change	
Pulses	No change	Note 3
Exported grains		
Rice	No change	
Maize	Decrease	Note 4
Tapioca	Decrease	Note 2
Grain sorghum	No change	
Pearl barley	No change	
Pulses	Decrease	Note 3
Exported perishables		
Asparagus	No Change	
Cut orchids	No Change	
Ginger	No Change	

Notes:
1.It is government policy to reduce cultivation of off—season rice crops for the next three years. Export quantity will be kept at the level of four to five million tonnes annually and emphasis will be on high quality rice and its processed products. There is also an increasing demand in the international market for "Green Rice," that is, rice not chemically treated.
2.Tapioca production is expected to be reduced in the near future due to lower demand in the international market. The government is trying to restructure tapioca production into other crops.
3. Pulses refer to leguminous grains including oil grains: white bean, red bean, mung bean, groundnuts, and soya bean.
4.Maize has ceased to be a major export commodity in the last five to eight years. It is now processed as a major ingredient in exported animal feed and is also used locally by the feed industry.

4.11. Economic Indicators for Key Sectors Using Methyl Bromide

TABLE 4.5
Economic importance of sectors using MB.

Export Earnings of sectors using MB	Million US$
Rice: approximately 4—5 million tonnes annually	1,597 — 1,818
Maize: not a major export in the last 8 years	29 — 163
Tapioca: Pelleted and semi—processed products	780 — 1,104
Animal Feeds: maize is a major ingredient	154 — 205
Pulses and Oil seeds	140 — 288
Perishables	145 — 284
Tobacco (dried leaves)	56 — 146
Sorghum	0.79 — 3.39
Black matpe beans	10.3 — 27.9
Mung beans	11.4 — 25.9

Note: MB is used on a variable proportion of the commodities in each sector. For example, only some types of tobacco (such as burley) are fumigated with MB.

4.12. Pests Controlled by Methyl Bromide

TABLE 4.6
Pests controlled by MB in selected commodities and crops.

	Commodities/Crops	Pests and Pathogens Controlled by MB
Grains	Rice	Maize weevil (*Sitophilus zeamais* (Motschulsky))
		Rice weevil (*Sitophilus oryzae* (Linn.)
		Red flour beetle (*Tribolium castaneum* (Herbst))
		Rice Moth (*Corcyra cephalonica* (Stainton))
		Saw—tooth grain beetle (*Oryzaephilus surinamensis* (Linn.))
		Flat grain beetle (*Cryptolestes pusillus* (Schonherr))
	Maize & Sorghum	Maize weevil (*Sitophilus zeamais* (Motschulsky))
		Red flour beetle (*Tribolium castaneum* (Herbst))
		Corn—sap beetle (*Carpophilus dimidiatus* (Fabricius))
		Rice Moth (*Corcyra cephalonica* (Stainton))
		Tropical wareyhouse moth (*Ephestia cautella* (Walker))
	Pulses	Cowpea beetle (*Callosobruchus maculatus* (Fabricius))
		Southern cowpea beetle (*Callosobruchus chinensis* (Linn.))
		Tropical warehouse moth (*Ephestia cautella* (Walker))
Root crops	Tapioca	Coffee bean weevil (*Araecerus fasciculatus* (Degeer))
		Larger grain borer (*Rhizopertha dominica* (Fabricius))
		Cigarette beetle (*Lasioderma serricorne* (Fabricius))
Perishables	Asparagus	Thrips (*Thrips tabaci*)
	Cut orchids	Thrips (*Dichromotrips corbetti*)

(chart continued on next page)

TABLE 4.6 (CONTINUED)
Pests controlled by MB in selected commodities and crops.

	Commodities/Crops	Pests and Pathogens Controlled by MB
Seedbed preparation	Tobacco Seedbed	Damping—off (*Pythium* spp.)
		Stem rot (*Rhizoctonia* spp.)
		Anthacnose (*Colletotrichum* spp.), (*Gloeosporium* spp.)
		Frog eye leafspot (*Cercospora nicotianae*)
		Brown spot (*Alternaria* spp.)
		Root knot nematode (*Meloidogyne* spp.: *M. javanica, M. napla, M. incognita*)

4.13. *Alternative Methods of Soil Pest Control*

The use of MB in crop production in Thailand is low (approximately 5% of MB consumption). The prime use is for soil—borne pathogens in seedbeds in tobacco production. Please refer to Tables 4.2 and 4.6.

TABLE 4.7
Examples of alternatives for soil.

Crop	Alternative Methods
Tobacco Seedbed Preparation *Note: Seedling production is done in the open field where a sheet of plastic net is sometimes used to reduce the intensity of sunlight*	*Nematicide and Herbicide.* Nematicides and herbicides are widely used in tobacco seedbed preparation. Examples of nematicides and herbicides are fenamiphos, oxamyl, bazamic G and roundup. These chemicals can be applied directly into the soil and require no covering sheet.
	Dry heat treatment. This method is an indigenous method of controlling soil pests. Local dry materials such as stems, grasses and straw are used to cover the seedbed and are burned to penetrate heat into the soil.
	Steam treatment. This method works on the same principle as the dry heat treatment but requires a simple steam generator. It is rarely found in Thailand.

4.14. *Alternative Methods of Pest Control for Stored and Export Commodities*

Phosphine, another fumigant, is currently used extensively to treat a large proportion of grain in storage. It would be technically feasible to increase the amount treated with phosphine, but cost is a constraint (see Table 4.8).

About 20—25% of grain exports are fumigated with phosphine prior to shipment. Many shipments need to be treated rapidly, so

Photo: CSIRO

Pressure testing to ensure sheeting will hold gas adequately, before a demonstration of phosphine treatment for sealed stacks of stored rice in Thailand.

increasing the use of phosphine is limited there. Changes in some pest management procedures could reduce the need for such treatments (Banks 1995).

Some types of tobacco are treated with MB. However, some importing companies (eg. Philip Morris) will only accept phosphine treatment.


Photo: CSIRO

Carbon dioxide is applied to a stack of stored rice after sheets have been sealed together and tested for adequate sealing (demonstration in Malaysia).

TABLE 4.8

Examples of alternative treatments for stored products.

Grain Storage	Alternative methods
Phosphine fumigation	Phosphine is used extensively for fumigating stored and exported grains. It is easier to administer but requires a longer exposure time than MB, and the cost of fumigation is a little higher: about US$0.60 per ton of grain as opposed to about US$0.52 per ton using MB. The cost quoted here of using phosphine is the commercial price using a German product. A Chinese product is now available at about 50% of the German one, but its quality and effectiveness have not yet been fully tested inThailand.
Carbon dioxide treatment	Carbon dioxide has been used commercially for some kinds of rice in small packages. Although CO_2 can be used as a fumigant it requires a much longer exposure time than MB and the cost of treatment per ton of grain, is reported to be much higher: about US$0.96 per ton.
Nitrogen atmosphere	Nitrogen has been tried commercially for fragrant brown rice in small packages but no extensive use of the technique has been found.
Sealed storage	A sealed small enclosure is a common technique found for food grains like rice and groundnuts. However, the technique, alone or in combination, could be feasible for long—term storage of large stacks where grain is kept enclosed.
Grain protectants	Several grain protectants can be used to control pest reinfestation during storage, but it is not able to provide eradication in already infested commodities.

TABLE 4.9

Examples of alternative treatments for export commodities.

Export Commodity	Alternative methods
Phosphine fumigation	Phosphine could be an alternative to MB. But fumigation with phosphine requires a longer exposure time than MB, which makes it less preferable when time is critical and costly. It is estimated that about 20 — 25 per cent of grain commodities are fumigated with phosphine prior to shipment.
Carbon dioxide treatment in transit	Carbon dioxide can be an alternative to the use of MB, but it is not now used in Thailand. In—transit CO_2 treatments are used for groundnut shipments in Australia (Annis, Banks & van Graver 1995). Its practical and economic aspects could be examined.
Nitrogen atmosphere	This is not presently used for exports but the practical and economic aspects could be examined.

4.15. Emissions Reductions

While efforts are being made to develop or apply workable alternatives to MB, which may take a few years, and research new fumigants, which will take even longer, it may be worthwhile to look at ways to make more efficient use of MB. An example is the development of systems where exhaust gas from one fumigated grain stack (after an exposure time is reached) can be introduced into another stack. This practice would reduce the amount of MB required for the new stack by as much as 40—50%, by just topping it up to the required concentration. Another area for study involves reduction of MB released into the air after fumigation.

C H A P T E R 5

Chile:

Methyl Bromide Use and Existing /Potential Alternatives

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THIS CHAPTER PRESENTS INFORMATION ABOUT CURRENT USES OF METHYL BROMIDE (MB) IN CHILE, ESTIMATED TONNAGES, AND VALUE OF SECTORS USING IT, AND AN OVERVIEW OF EXISTING AND POTENTIAL ALTERNATIVES.

5.1. Imports of Methyl Bromide

Methyl bromide is commonly used as a fumigant for controlling a wide range of pests, insects and nematodes in Chile. It can also be effective in the control of many weeds and seeds contained in the soil. Methyl bromide is not manufactured in Chile. It is imported from Israel, Belgium and the USA. Israel provides the largest quantity with 49.2%, followed by Belgium with 27.6%, and the USA with 23.2% of the total volume imported between 1992 and 1994 (Figures from ODEPA, 1995).

In Table 5.1 the volumes of MB imported are given by country of origin from 1990 to July 1995. The average for 1990 to 1994 was 282 tonnes per year. Use declined from 336 tonnes in 1990 to about 200 tonnes in 1994, but appears to be increasing in 1995.

TABLE 5.1
MB imports by country of origin (tonnes net).

Country	Year					
	1990	*1991*	*1992*	*1993*	*1994*	*1995**
USA	142.60	80.72	76.72	89.84	31.53	16.85
Belgium	75.61	89.14	106.82	87.57	40.27	35.97
Israel	117.69	86.50	135.95	122.48	127.18	144.25
TOTAL	**335.90**	**256.36**	**319.49**	**299.89**	**198.98**	**197.07**

Source: Central Bank of Chile. * *Figures to July 1995*

The smaller volume imported in 1994 can be explained by imports accumulated in the previous two years, due to the expectation of increased fumigation in fruit to be exported to the USA. This would have been carried out according to a program by U.S. Department of Agriculture and SAG, the Chilean quarantine authorities, promoting increased fumigation in countries of origin, but the program was cancelled before having been put into effect.

When used as a soil fumigant, MB can be injected directly or applied by irrigation systems using a dosage of 400-450 kg/hectare. When applied to fruit in compliance with USA conditions, the application is undertaken in 300 m^3 fumigation chambers, designed and constructed according to USDA specifications. The dosage varies according to the condition and temperature of the fruit as established by the quarantine treatment T 101(a) of the USDA (see Table 5.12).

Methyl bromide can be obtained in formulations with differing concentrations according to the use in question; for fruit fumigation 100% MB is used, while for soil fumigation concentrations of 75% or 98% can be used. Methyl bromide is distributed in containers weighing from 10 to 200 kg. It also comes in small canisters of 0.5 to 1 kg.

There are three main distributors of this product in Chile: Degesch de Chile Ltda., Agricola Nacional S.A.C. Industrial (Anasac) and Bayer de Chile Ltda. Table 5.2 shows the US$ range of the principal importing firms.

TABLE 5.2
Classification according to the range of imports in US$.

Company	Range of Imports (US$)
Del Curto	30,000 - 60,000
Degesch de Chile Ltda.	60,000 -150,000
Chiletabacos	60,000 -150,000
Bayer de Chile S.A.	150,000 -500,000
Anasac	150,000 -500,000

Source: Pro-Chile 1994.

TABLE 5.3
MB imports for 1994 (tonnes).

Importer	Weight (tonnes)	Percentage (%)
Desgech de Chile Ltda.	31.53	15.8
Bayer de Chile S.A.	40.27	20.3
Anasac	127.18	63.9
Total	**198.98**	**100.0**

Source: Aduana (Customs Office).

5.2. Estimates of Use of Methyl Bromide

There is no precise data as yet about the usage of MB in Chile. In part this is because the importing companies do not keep detailed records of the many small farmer clients with variable fumigation requirements. Furthermore, there are no official statistics concerning the use of MB in Chile. It is only possible to obtain information where large amounts are sold or where the consumers are organised, as is the case with fruit and vegetable exporters (Associacion de Exportadores de Chile A.G.).

TABLE 5.4
Estimates of total quantity of MB consumed in Chile, 1991 - 1994.

Year	Estimated quantity of MB used in Chile (tonnes)
1991	375.7
1992	128.7
1993	210.6
1994	230.7

5.3. Sectors Using Methyl Bromide

According to data for 1994, approximately 70% was used for soil fumigation; 22% was used for fruit fumigation; and the remaining 8% was put to other uses in the forestry sector and in the fumigation of warehouses (these figures are drawn from a variety of sources) (see Figure 5.1).

According to the information collected so far, the main crops where MB is used for soil fumigation are the following:

- fresh tomatoes;
- fresh peppers;
- production of pepper seeds;
- industrial tomato seedbeds;
- seedbeds for tobacco production; and
- fruit tree seedbeds in nursery greenhouses

The following crops require quarantine fumigation in order to be allowed entry into the USA: table grapes, chestnuts, citrus fruits, nectarines, peaches, plums and apricots.

Information received from two forestry companies that export wood to the USA shows that there is a requirement for MB treatment at a dosage of 80g/m² of wood. The total volume involved is not known.

In the 1994/95 season, Chile exported approximately 63 million boxes of table grapes, of which about 35 million went to the USA. Fourteen percent of the total amount of fruit exported (and 25% of the fruit exported to the USA) was fumigated in Chile. However, all the table grapes exported to the USA are required to be treated with MB, whether at the point of origin or at the destination, before entering the USA.

TABLE 5.5
The usage of MB in Chile in 1994.

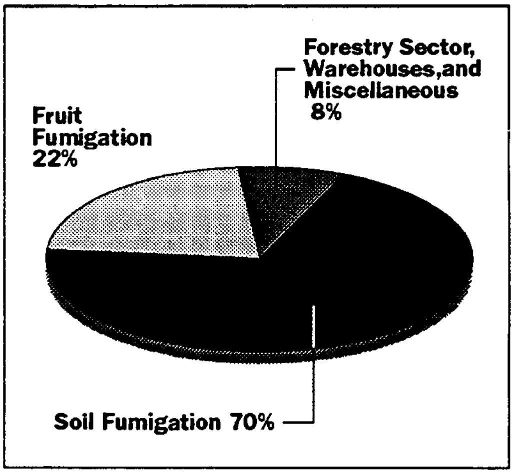
Usage	Weight (tonnes)	Percentage (%)
Soil fumigation	140.00	70.0
Fruit fumigation	45.00	22.0
Grain post-harvest	0	0.0
Other	16.00	8.0
Total	**201.00**	**100.0**

TABLE 5.6
Boxes of fruit fumigated in Chile with destination USA in 1994/95.

Species of fruit (boxes)	
Apricots	11,076
Nectarines	163,777
Plums	203,721
Peaches	204,445
Table grapes	9,069,054

Source: Association de Exportadores de Chile A.G. 1995.

FIGURE 5.1
Major applications of MB in Chile.



5.4. Crops for which Methyl Bromide is Used

Table 5.7 lists all crops grown on soil treated with MB in Chile.

TABLE 5.7
Crops grown on soil treated with MB.

Name of Crop	MB used for open field crops	MB used for glasshouse and covered crops
Vegetables		
Tomatoes	Used for seedbeds	Soil and seedbeds
Peppers	Used for seedbeds	Extensive use with seeds
Fruit, Orchards, Nut Trees		
Fruit and nut trees	Soil fumigation for nurseries	
Flowers, Ornamental Plants		
Roses	For use with seedbed soil (eventually)	
Other Crops		
Other vegetables (onions, lettuce, eggplant etc.)	Used for seedbeds	
Tobacco	Used for seedbeds	
Forest trees	Used for seedbeds and nurseries	

5.4.1. Fresh Tomatoes and Peppers

Currently there are over 2,000 hectares of tomato greenhouses. The hectáres in the central region of Chile are fumigated at least once per season, since there are two annual harvests, spring (July to December) and autumn (January to May). The main objective of this fumigation is to control the fungus *Pyrenochata lycopersici* which causes root damage in tomatoes. The high cost of tomato production under plastic and the potentially high profitability of this crop, makes the use of MB important as it guarantees the establishment and adequate density of the plants.

Some producers are exporting tomatoes to Argentina for which there is a MB fumigation requirement, which explains the appearance of tomatoes in Summary Table 5.11.

There are approximately 3,300 hectares of peppers under cultivation, of which no more than 5% are under plastic (165 hectares) and fumigated. Where peppers are grown as a second crop after the autumn tomato, only one of the two crops would be fumigated per season, which complicates the estimate of the area fumigated. The main objective of fumigating peppers grown for fresh consumption is to control the fungus *Phytophtora* spp., which causes pepper wilt.

5.4.2. Pepper Seed Production

The production of hybrid pepper seeds has grown significantly in recent seasons, especially in the Fifth Region and the Metropolitan Area of Santiago where greenhouse cultivation under plastic is concentrated. Given the high costs involved in the production of hybrid seeds, MB is used to fumigate the soil.

5.4.3. Agroindustrial Tomato Seedbeds

Tomatoes for agroindustrial processing are cultivated on approximately 12,000 hectares: only the part used for seedbeds is fumigated. It is calculated that to plant one hectare, 100 m^2 of seedbeds are needed. Accordingly, the total area fumigated in the production of tomatoes for agroindustrial use is 120 hectares.

5.4.4. Tobacco Seedbeds

Currently 5,000 hectares are cultivated for tobacco in Chile. Of this area only the soil used for seedbeds is fumigated. For each hectare of tobacco plants, 100 m^2 of seedbeds are required, meaning that approximately 50 hectares are fumigated.

Table 5.8
Area of crops with MB soil fumigation (hectares).

Crop	Area Cultivated (hectares)	Area Fumigated (hectares) (%)
Greenhouse tomatoes	2,114	1,000 (47%)
Greenhouse peppers	165	165 (100%)
Pepper seeds	38	38 (100%)
Industrial tomato (lands)	11,590	120 seedbeds
Tobacco (lands)	5,000	50 seedbeds
Total	**18,907**	**1,378**

Source: Estimates based on information from ODEPA.

5.5. Quantities of Methyl Bromide Used for Soil

Table 5.9
Dosage and cost of MB (with chloropicrin).

Product	Dosage (kg/hectare)	Cost per kg (US$)	Cost per hectare (US$)
680 g canister	450	5.1-7.3	2295-3285
98% injections	450-800	3.5	1575-2800
75% injections	450-800	5.0	2250-4000

Source: Market prices in Quillota, Fifth Region.

Soil fumigation with MB can be done by direct injection or by piped systems of irrigation. The dosage of MB varies according to the concentration of chloropicrin with which it is mixed, and may vary between 450 kg/hectare and 800 kg/hectare. When fumigating by irrigation, two 680 g canisters are used for each 15 m2 of soil. This gives a total of 450 kg/hectare since only the planted areas, which amount to 50% of the total surface area, are fumigated. When MB is injected into the soil, the dosage varies from 45 to 80 g/m^2, which translates to 450 kg/hectare to 800 kg/hectare.

The 680 g canisters are priced between about US$3.5* and 5.00 each plus value-added tax (VAT) (18%). For the injected MB (with chloropicrin) the costs are about US$4.20 for the 98% formulation and about 4.60 for the 75% formulation, in addition to the cost of the injecting equipment. For case studies on costs see Chapter 7 (* = Chilean $390).

5.6. Proportions of Crops Using MB and Using Alternatives

Table 5.10 shows estimates of the area of crops treated with MB and with other pest control methods in 1994. Alternatives are in use for each of the main crops. They are used on a very small percentage (about 5%) of the area of pepper seeds. Alternatives are used on 15 - 40% of the area of three major crops. Tomatoes under plastic have the largest area using alternatives - about 100 hectares, although this is a small proportion of the total crop area (5%).

TABLE 5.10
Proportion of crops grown with MB and alternatives.

Name of crop	Total area cultivated 1994 (ha)	Area treated with MB in 1994 (ha)	Area using other pest control methods (ha)
Tomatoes (under plastic)	2.114	2.008	105 (5%)
Peppers (under plastic)	165	140	25 (15%)
Pepper seeds	38	36	2 (5%)
Tomato for industry (seedbeds)	120	84	36 (30%)
Tobacco (seedbeds)	50	30	20 (40%)

5.7. Potential Alternatives to the Use of Methyl Bromide

A wide variety of products have been used for soil fumigation, but have proved to be less effective than MB. The following should be mentioned:

Metam sodium and metam potassium products do not need covering when applied to soil. The dosage used varies between 100 and 200 cc/m^2 . They do not keep weed seeds or the fungus *Pyrenochaeta lycopersici* under control, which limits their use with tomato crops.

Formalin, also known as formaldehyde, is rarely used now due to its inefficiency. It is applied to the soil via irrigation 20 to 40 days before planting in doses of between 250 and 300 cc/m^2. It has been listed by the International Agency for Research on Cancer (IARC) as an animal carcinogen, so handling it may pose safety problems.

Dazomet is a product that comes in powder form and is used in doses of 60 g/m^2. It must be applied via irrigation water or using polyethylene covers. This has shown itself to be the best alternative for replacing MB and is already being used in experimental form for the fumigation of industrial tomato seedbeds, tobacco and the production of hybrid seeds (see Table 5.14).

Enzone is a wide spectrum disinfectant used to control *Phytophthora* spp. and *Pyrenochaeta lycopersici.* The dosage varies between 20 and 25 litres/1000m^2 in four applications via irrigation. This product has been used in Spain but produces toxic gases when mixed with acidic substances, which makes it dangerous to human health.

Solarisation consists of covering an area of soil with transparent polyethylene and leaving it exposed to solar radiation for 20 to 30 days. This technique has been well developed in Spain and a number of other countries with high levels of solar radiation.

Its drawbacks in Chile are its current costs (see Chapter 7) and the lack of an adequate method for placing and removing the plastic from the soil. In Chilean conditions it is an interesting alternative for use with seedbeds in areas of high solar radiation and its capacity to control diseases specific to Chilean soils should be evaluated. Currently it is being studied and evaluated by some producers.

Steam treatment (vaporisation) is a very effective method which can even destroy viruses. Temperatures of 85° Celsius must be reached for a period of 30 minutes by injecting steam into soil. It is widely used in nurseries, but it is restricted to small volumes of soil, due to the high infrastructure and fuel costs for this method as currently practiced in Chile.

The methods and techniques described here need to be evaluated and validated for use in local conditions to determine whether they provide adequate and economically viable alternatives to MB in Chile.

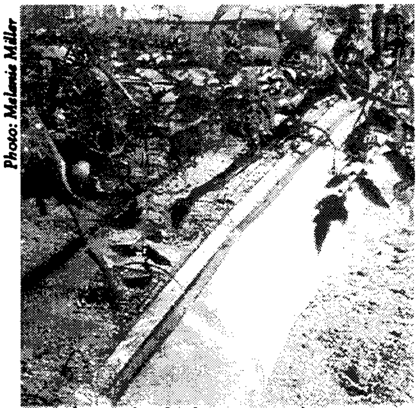


Photo: Melanie Miller

Use of natural soil substitutes - in this case gravel - for growing tomatoes in farm trials in Chile.

5.8. Potential Alternatives to Methyl Bromide for Fruit Fumigation

Of those species requiring fumigation with MB in order to comply with quarantine conditions, the most important in terms of the volume exported is the table grape. It must be fumigated because it is host to the vine spider mite *(Brevipalpus chilensis)*, a quarantine pest in the USA. The establishment and development of an alternative pilot plan is being studied that involves the phytosanitary treatment of vineyards. This aims to control *Brevipalpus chilensis* in order to obtain a declaration that the area is accredited by SAG, the Chilean quarantine authorities, and recognized by USDA as free of the spider mite.

Another alternative for the treatment of fruit is the use of ultraviolet light pulses (lasers). These UV laser systems have potential for the surface control of bacteria, fungi and viruses. Furthermore, with light intensities at 250-280 nanometers (nm), it is possible to maintain surface control of insects and mites. This may enable an improvement in the handling, transportation and prolonged storage of the fruit. The feasibility of implementing this system for table grapes is currently being evaluated. The main drawbacks are economic and technical, arising from the high cost of the system and from the need to adapt the packing structures to the application of UV light pulses.

Another alternative to the use of MB is the application of natural waxes to the fruit. This technique is used with custard apples and some citrus fruits such as lemons, and is at an experimental stage with mandarins. It consists in covering the fruit with a layer of wax, which impedes fruit deterioration and asphyxiates insects already present.

It has been possible to develop the alternative of inspecting stone fruits in the country of origin and in the destination country so as to avoid fumigating with MB. This method of pre-inspection and certification is a widely used quarantine procedure around the world. However, the results achieved in Chile have been erratic, since an adequate control system for the presence of quarantine insects has not yet been established.

The use of MB (USA quarantine treatment T 101) is not required in species such as asparagus and raspberries, but fumigation takes place in some instances to eliminate insects that might cause imports to be rejected.

Other possible alternatives that will have to be studied in order to evaluate their effectiveness on quarantine pests are:

- the application of cold treatment;
- the use of modified atmospheres, achieved by altering the relative concentrations of oxygen and carbon dioxide; and
- the utilisation of techniques involving high pressure followed by rapid decompression (the OEX method), which is under study in developed countries.

TABLE 5.11

Alternative quarantine treatments for fruit.

Species	Treatment (existing and potential)
Table grapes	Vineyard free of spider mites
	UV light pulses
Stone fruit	Double inspection USDA/SAG
	Cold treatment
	Modified atmosphere
Lemons	Waxing
Mandarins	Waxing

TABLE 5.12

List of commodities treated with MB and other treatments.

Name of Commodity	Post-harvest treatment excluding quarantine	Quarantine treatment
Table grapes	SO_2 as gas	Treatment T-101 with MB
Citrus fruit	Waxing	
Nectarines		Treatment T-101 or USDA-SAG inspection
Peaches		Treatment T-101 or USDA-SAG inspection
Plums		Treatment T-101 or USDA-SAG inspection
Apricots		Treatment T-101 or USDA-SAG inspection
Tomatoes		MB fumigation
Asparagus	MB fumigation	
Strawberries	MB fumigation	

TABLE 5.13

Economic indicators for key sectors using MB.

Name of crop or commodity	Export value in 1994 (US$ million)	Number directly employed 1994 (LD=Labour day=8hrs)	Number indirectly employed 1994 (LD)
Table Grapes	300,0 [1]	9.717 LD [2]	819.336 LD [3]
Nectarines	24,8	175 LD	17.420 LD
Peaches	27,3	219 LD	57.712 LD
Plums	55,0	218 LD	612 LD
Apricots	3,7	12 LD	131 LD
Tomatoes	5,1	450 LD	5.880 LD

Notes:
[1] *Estimated value of the total exported to USA.*
[2] *Only the people directly involved in MB fumigation are included.*
[3] *This refers to the people involved in the production of the fruit that is fumigated.*

There is also an apparatus in Chile (made by Halozone in Canada) which can be fitted to a fumigation chamber to recycle part of the MB used for fruit. But the equipment has not been used due to the lack of resources to put it into operation and to evaluate its effectiveness. The export sector and the research institutes INIA and INTEC in Chile have requested foreign funds to evaluate this equipment but have not yet received a positive response. Evaluations carried out by the firm itself show that it is possible to recapture a significant proportion of the MB remaining available in chambers after fumigation. However, the capital cost of the equipment is very high and it consumes a significant amount of energy.

TABLE 5.14

List of pests controlled by MB in selected major crops and commodities.

Name of Crop	Biological names of pests controlled by MB
Tomatoes	1. - *Pyrenochaeta lycopersici*
Peppers	1. - *Phytophthora capsici*
Forestry (seedbeds)	1. - *Macrophomina phaseolins*
Fruit Trees (nursery and adult)	1. - *Armillaria* spp.
Table grapes	1. - *Brevipalpus chilensis*
Vegetable seedbeds	1. - *Rhizoctonia* spp. 2. - *Phytium* spp. 3. - *Fusarium* spp.

Note: Only the principal pests and diseases are mentioned.

C H A P T E R 6

Methyl Bromide Alternatives:

Description and Yields

THIS CHAPTER OUTLINES THE ALTERNATIVE PEST CONTROL TECHNIQUES IDENTIFIED BY THE METHYL BROMIDE TECHNICAL OPTIONS COMMITTEE (MBTOC) REPORT, AND THEIR MAIN ADVANTAGES AND DISADVANTAGES. IT GIVES FURTHER EXAMPLES OF EXISTING ALTERNATIVES THAT COULD BE APPLIED IN DEVELOPING COUNTRIES. IT ALSO PROVIDES EXAMPLES OF THE CROP YIELDS GIVEN BY ALTERNATIVES AND METHYL BROMIDE (MB).

6.1. MBTOC Report

MBTOC identified alternative, effective methods of pest control; it did not examine economic information. The MBTOC report identified technically feasible alternatives, either currently available or at an advanced stage of development, for a substantial proportion of MB use (MBTOC 1994:3). These included some alternative treatments for quarantine. MBTOC noted that alternatives, and the potential constraints on their use, are generally the same in developing countries as in industrialised countries. However, their application is generally further constrained by the social conditions, level of infrastructure and other conditions typical in many developing countries (TEAP 1995:69).

6.2. Importance of IPM Approach

To control the broad spectrum of pests controlled by MB, it is often necessary to use combinations of practices or techniques. The most effective and suitable combination will vary according to the crop, commodity, pests and local situation.

MBTOC noted that to implement alternatives to MB an Integrated Pest Management (IPM) strategy will be required (MBTOC 1994:64). IPM is a systems approach, which aims to prevent and manage pest problems in an environmentally sound and cost effective manner, minimising the use of pesticides (Pimental 1981). MBTOC points out that this approach is needed to avoid future environmental problems (MBTOC 1994:70).

As a replacement for MB, IPM involves detecting and monitoring pests and beneficial organisms; establishing economically acceptable levels of pests; selecting a mix of techniques to enhance natural controls and predators and prevent pest build-up; physically removing pests or weeds; using the least-toxic, target-specific pesticides where cultivation techniques and biological controls cannot control a pest. IPM generally replaces chemical inputs with inputs of skill and knowledge.

Horticultural holdings in some developing countries have introduced IPM very successfully. For example, an IPM programme for tomatoes in Mexico was found to give similar or higher yields than conventional production; net profits ranged from US$304 to 579 per hectare higher using IPM (Trumble & Alvarado-Rodriguez 1993). IPM adopted by many growers in Sri Lanka has increased yields and more than doubled profits in vegetable production (Jones 1996). Cut flower producers in Colombia have replaced MB with a combination of IPM and composting, which is both effective and profitable (Rodriguez-Kabana & Martinez-Ochoa 1995).

The major barrier to introducing IPM is that it requires an initial investment in training as well as research/development to apply the technique locally. However, the initial investment can often produce long-term cost savings. A detailed evaluation of large-scale IPM programmes by the Food and Agriculture Organisation (FAO), for example, found that training farmers in IPM improved crop yields and substantially reduced pesticide expenditure in each of the seven Asian countries studied in detail (FAO 1994).

Pest and predator monitoring is a very important part of IPM. Monitoring and economic threshold systems are well developed for some key insects, mites and nematode pests, but at present are poorly developed for some plant pathogens. Further research is needed for this area in particular. In Zimbabwe, for example, there has been a relatively small amount of research into natural pest predators and competitors, so horticulture could gain considerably from further research of this type (Wilkinson 1992). Effective use of sampling would require training at the farm level. Several commercial techniques exist to assist accurate monitoring of soil pests - insects, mites, nematodes, pathogens, viruses and weeds (MBTOC 1994:70). These include:

- a variety of 'traps' and surfactant drenches to detect insects and mites; and
- seed sampling to detect weeds (MBTOC 1994:70).

6.3. Soil Alternatives Identified by MBTOC

This section provides an overview of the alternative soil pest control techniques identified by MBTOC, and their general advantages and disadvantages. The MBTOC report divided alternative soil techniques into several groups, which are described below. In most cases several techniques need to be used in the context of an IPM system, to fully replace MB. The alternative soil techniques are:

- changes in cultural practices;
- biological controls;

- waste organic materials (soil amendments);
- physical treatments; and
- chemical treatments.

6.3.1. Changes in Cultural Practices

MBTOC concluded that it is possible to develop systems of cultivation practices for specific localities to reduce or eliminate use of MB (MBTOC 1994:75). In most cases a prerequisite is a good understanding of pest dynamics and the ecology of the field system. Cultural practices include crop rotations, controlling plant nutrition, deep ploughing and cover crops.

6.3.1.1 Crop Rotation

Changing crops from year to year, in a carefully selected cycle, is a traditional and widespread pest control technique. Where growers have sufficient space, horticultural crops may be alternated with crops that break pest life cycles and help prevent pest build-up. Crop rotations are effective in controlling many soilborne pests in various parts of the world (MBTOC 1994:64). Strawberry producers in Germany, for example, adopted crop rotation as a major technique for replacing MB when it was prohibited for food crops in 1985 (Ketzis 1992). Some German horticulturalists exchanged the use of fields with other farmers nearby when they had insufficient space to rotate fields within their own farms (Ketzis 1992).

The advantages of crop rotation to horticulturalists include simplicity, no human or environmental safety problems, no chemical residue problems (which can affect the marketability of crops), and opportunity to build up natural soil predators. The main barriers include access to information about suitable rotations, insufficient land for rotation, or insufficient profit from the rotation cycle in some cases. Prior heavy investment in capital equipment suitable for only one type of crop also mitigates against rotation. In Zimbabwe, for example, rotation of tobacco seedbeds is recommended by the Tobacco Research Board, but irrigation facilities often restrict the ability to rotate.

6.3.1.2. Plant Nutrition and Soil pH

Adequate, balanced plant nutrition can help to reduce the impact of soilborne pests (MBTOC 1994:75). For example, phytonematodes are sometimes inhibited by sources of urea or ammoniacal nitrogen which affect microbial activity in soils (Franco et al 1993). Ammoniacal nitrogen sources (eg. ammonia, ammonium carbonate and ammonium bicarbonate) can reduce damage from *Sclerotium rolfsii* in carrots and other crops (Punja 1985). Pod rot (*Pythium myriotylum, Rhizoctonia solani, Fusarium* spp.) in peanut has been reduced by applying lime (calcium carbonate) or landplaster (calcium sulphate) to enhance calcium nutrition (Pattee & Young 1982). In some cases a change in soil pH is sufficient to reduce certain soil pests (Cook & Baker 1983). A great deal can be done to reduce disease through appropriate management of plant nutrition and soil pH (MBTOC 1994:75).

Appropriate sources of nutrients need to be carefully selected to avoid environmental problems or over-nutrition. Readily available nutrients in synthetic fertilizers can have negative environmental impacts, such as emitting nitrous oxides to the atmosphere (Conway & Pretty 1991). Nutrients that are slowly released from decaying organic waste matter are preferable.

The technique requires knowledge of plant nutrition, and the availability of suitable sources of nutrients. For horticulturalists, the main advantages would be minimal human safety problems, and low environmental impact if the source and type of nutrient is carefully selected. The main barriers are the lack of knowledge and information about nutrition and soil pH.

6.3.1.3. Deep Ploughing

Deep ploughing can reduce pathogen levels by burying their reproductive structures and by stimulating microbial activity and decomposition of crop debris (MBTOC 1994:74). For example, the number of sclerotia of *Sclerotium rolfsii* in soil can be reduced significantly by deep burial. This technique has been practiced for a long time in the production of peanuts *(Arachis hypogaea)* and other crops in the USA to reduce southern blight (Punja 1985). The technique requires deep ploughing equipment and knowledge about the crops and pathogens for which the technique will be effective.

The main advantages of this approach would be low human or environmental safety problems and absence of chemical residues. The main barriers are lack of knowledge about suitable pathogens and lack of suitable plough equipment.

6.3.1.4. Cover Crops and Living Mulches

Cover crops are non-commercial crops that are turned into the soil as green or dry residues. For example, in Florida, winter vegetables may be preceded by summer cover cropping with sorghum *(Sorghum bicolor)*, sudan grass (*Sorghum* spp.), jointvetch *(Aeschynomene americana)* or hairy indigo *(Indigofera hirsuta)* (MBTOC 1994:74). This reduces damage from nematodes and other soilborne pathogens in the vegetable crops (McSorley et al 1994). Cover crops must be carefully selected so that they complement, rather than compete with, the commercial crop. In Zimbabwe, selected cover crops are planted in tobacco seedbeds to help reduce nematodes.

A living mulch is another form of cover crop grown at the same time as the commercial crop. It can suppress weeds, reduce tillage and insect pests, without reducing yields (Thurston et al 1994). Mulching can also help to control pest insects by mechanisms such as repelling or possibly confusing them, by attracting natural enemies, or by reducing the visibility of the commercial crop (MBTOC 1994:75).

The main advantages of this approach are the absence of human or environmental safety problems, the opportunity to build up natural predators, extra plant nutrients in some cases, and cost-savings in weed control/tillage. The main barriers are lack of knowledge and information about suitable cover crops and mulches, and cost of seeds, planting and ploughing in.

6.3.1.5. Timing of Planting

Certain crops can be planted when plant pathogen levels are low and/or conditions are not conducive to disease development. This approach was demonstrated to be effective in Georgia, USA, where damage from root knot nematodes was maintained at low levels through a combination of crop rotation and early planting to avoid periods when nematodes were likely to flourish (MBTOC 1994:74). In developing countries, this technique may be feasible for crops with production and marketing windows that fit with low pest windows. Knowledge of the population dynamics of plant pathogens would be required.

The main advantages of this approach would be the absence of human, environmental or residue problems, and minimal cost. The main disadvantage is that it is only suitable for certain crops and pests. In Zimbabwe, there is a closed season for tobacco when it may exist only in seed form; this legal requirement was introduced as a disease control measure.

6.3.2. Soil Substitutes

In nurseries, glasshouses, shadehouses and some other situations, soil can be replaced with natural or synthetic substitutes such as rock wool, tuff stone, clay granules, volcanic pumice, coal slag, charcoal or clean 'waste' materials such as disease-free grain hulls or bark from forest industries. Re-usable materials such as clay granules and rock wool need to be sterilised between crops, with steam for example (Nordic Council 1993). Waste materials such as grain hulls can be replaced each season.

Photo: Natalia Martinez-Ochoa

Substrate (coal slag) being steam sterilised for use in propagation beds in the successful cut flower industry in Colombia.

The use of soil substitutes has proven the technical and economic feasibility of eliminating the use of MB in greenhouses in the Netherlands (MBTOC 1994:75). In Italy, Denmark and the Netherlands, soil substitutes have given significantly higher yields than soil fumigated with MB (Vickers 1995; Nordic Council 1993; De Barro 1995) (see Section 6.5). Some of the systems in the Netherlands systems have been capital intensive and technologically based, however, cheaper substrate systems are also used there. Cheaper soil substitutes are feasible for many countries. Rice hulls are used in the flower industry in Colombia; and mixtures of porous basalt, perlite and agilla are used for tomatoes in Sicily. A producer in Chile has experimented with growing lettuce on grain hulls, and tomatoes on gravel.

6.3.3. Biological Controls

There are many beneficial soil organisms that can damage or compete with soil pests. A great deal of scientific literature is available, describing many organisms antagonistic to plant pathogens (MBTOC 1994:71). Beneficial organisms (biological controls) can be carefully selected, reared commercially and introduced into soil. They need to be placed in an unoccupied niche or in large amounts in colonised substrate before they can overwhelm competing or pest organisms. In some cases they partially reduce disease levels, in other cases they prevent disease from occurring (MBTOC 1994:72). Each biological control is normally active against very specific pests, so appropriate organisms need to be selected for different pests and conditions. To help replace MB they would normally have to be used with other techniques.

In a few cases biological controls have been in use for many years (MBTOC 1994:73). The efficacy varies considerably under different cultural and environmental conditions. There is a growing body of research which shows that soilborne insect pests, in particular beetle and moth larvae, can be controlled by fungal and bacterial pathogens and entomophilic nematodes (Hill 1995). For example, fungal pathogens, mostly in the genus Beauveria, are used to control white grub in sugarcane in Reunion and Mauritius. A fungal pathogen as an alternative to EDB is being developed in Tanzania for the control of white grub in soil (Hill 1995).

In the future, use of antagonistic *Fusarium* spp. and/or fluorescent Pseudomonads, active against several *formae speciales* (f.sp.) of *F.oxysporum* (f.sp. *dianthi*, f.sp. *lycopersici*, f.sp. *cyclaminis*, f.sp. *melonis*, f.sp. *basilicum*) may permit control of *Fusarium* wilts and other diseases (MBTOC 1994:72). Use of *Trichoderma* spp. as seed dressing or soil treatment may help to control damping-off and root rots caused by *Phytophthora* spp., *Pythium* spp. and R. Solani (Cole & Zvenyika 1988). Many of the soilborne pests of concern in horticulture in Africa are indigenous (for example white grub, cutworm, wireworm), and may therefore be amenable to control by enhancing the impact of the large number of indigenous natural enemies that occur naturally in African agro-ecosystems (Hill 1995).

Trichoderma, *Gliocladium* and a few other biological controls have been registered and commercial preparations are available in a number of countries (Katan 1993). So far, less than six commercially available biological control agents for soil are available (MBTOC 1994:72).

In Zimbabwe, *Trichoderma* is produced commercially; it is used in tobacco seedbeds, and is being tested for strawberries. It is also used in tobacco seedbeds in the Philippines, allowing reduced use of pesticides.

A commercial form of *Gliocladium* has recently been officially registered (approved) in the USA for controlling damping off and root rot pathogens of ornamental and food plants in nurseries and greenhouses; registration will be extended to open field use (Lumsden et al 1996). *Gliocladium virens* suppresses soilborne diseases caused by pathogens such as *Pythium*, *Rhizoctonia* and *Sclerotium rolfsii*.

For pests originally introduced from other countries (exotics) it may be necessary to import natural predators because there are normally no indigenous ones. From an environmental perspective, it is necessary to ensure that any imported, non-indigenous predators will not cause unanticipated problems for the local ecology or agriculture. Researchers working with biological controls have, for a long time, taken account of this when developing controls. A FAO code of practice on biological control has recently been drawn up.

Biological controls offer developing countries the advantages of no adverse effects on other beneficial organisms, no chemical residues and low or absent environmental problems if biological controls are carefully selected. The main disadvantages are the very specific activity of some (but not all) biological controls, the need for re-inoculation, the lack of sufficient research and development to date, and the lack of farmer knowledge.

6.3.3.1. Rhizobacteria

Rhizobacteria are bacteria that live in and around the roots of plants. Many are antagonistic to pathogens and can establish a 'biological shield' around plant roots, delaying invasion by nematodes or other pathogens (MBTOC 1994:72). Rhizobacteria could prevent attacks from a broader range of organisms than normal for biological controls. Rhizobacteria also can produce the beneficial side-effect of promoting plant growth (Suslow 1982). There are several commercial rhizobacteria products that have been tested successfully under field conditions (MBTOC 1994:72).

6.3.3.2. Mycorrhizae

In natural situations, almost all plant roots develop in close association with specialized fungi forming a complex, the mycorrhizae. Mycorrhizae inhibit growth in some plants. In others they encourage roots to proliferate and increase the surface for absorbing nutrients (MBTOC 1994:72). Certain plants with mycorrhizae have been found to be more resistant to soilborne diseases (Calvet et al 1993, Chet 1987). A few commercial products are available (Rodriguez-Kabana & Calvet 1994). However, they are limited to certain crops and may not be suitable in soils with a high level of readily available nutrients.

6.3.4. Plant Breeding and Grafting

Systematic, scientific plant selection and breeding began almost a century ago and has produced crop cultivars resistant to many soilborne pests (MBTOC 1994:75). For most crop species there are varieties tolerant or resistant to root-knot nematodes or to pathogenic fungi such as *Phytophthora, Fusarium, Verticillium* and *Sclerotinia* (MBTOC 1994:76). Selectively breeding new resistant varieties may take 5-15 years. Cultivars are usually resistant to one rather than several pathogens. However, in certain cases they can help to replace MB. In Zimbabwe, for example, some nematode resistant cultivars of tobacco are commercially available.

Grafting susceptible plants onto pathogen-resistant rootstock is traditionally used for orchards. More recently, efficient grafting techniques have been developed for annual crops, such as tomato, eggplant and cucurbits, to allow production of the crops without fumigation (MBTOC 1994:76). Tomatoes, for example, can be grafted onto *Solanum torvum* rootstock to obviate damage from root-knot nematodes and bacterial wilt (*Pseudomonas* spp.). Similarly, melons or cucumbers can be grafted onto wild melon or pumpkin rootstock to avoid problems caused by *Fusarium* wilt pathogens (Gomez 1993). In some cases, grafting techniques can economically and efficiently permit production without fumigation (MBTOC 1994:76). Grafting also has the benefit of allowing growers to make a rapid response to market demands (MBTOC 1994:76).

6.3.5. Natural Materials and By-products

Natural (organic) materials added to soil can help to manage pests and diseases as well as improve fertility. A wide variety of natural materials - called soil amendments - have been tested in managing nematodes, soilborne phytopathogenic fungi and weeds. Materials include livestock manure, waste chips and bark from forest industries, waste paper, oil cakes, materials from seafood and fisheries operations (such as shrimp shells), sewage, and by-products from agriculture, food and other industries (MBTOC 1994:70). There is a large body of scientific knowledge on the use of such materials for the management of soilborne pathogens (Cook & Baker 1983, Hoitink 1988).

Efficacy of the materials depends on their chemical and physical properties, which determines the type of soil microorganisms involved in their decomposition. Some materials containing nitrogen (such as urea and guanidines) generate ammonia which can be nematicidal (Canullo 1991, Canullo et al 1992). Chitin or chitinous materials generate ammonia and stimulate chitinolytic microorganisms in soil (Rodriguez-Kabana eta al 1983, 1989, 1990). Many of these destroy nematode eggs and mycelia of certain phytopathogenic fungi. Hardwood bark (composted or not) usually improves plant growth and helps to suppress pests. Bark composts support higher levels of antagonistic microorganisms and show good antagonistic activity against *Phytophthora* spp., *Pythium* spp., *Rhizoctonia solani* and several formae speciales of *Fusarium oxysporum* (MBTOC 1994:71).

To be effective, large amounts of material normally need to be added to soil - more than 50 tonnes per hectare (MBTOC 1994:71). However, if other treatments are used, the quantity of material can be reduced. For example, the combination of solarisation (see below) with reduced amounts of waste material offers considerable potential to increase efficacy against pests (Gamliel and Stapleton 1993).

Materials can be relatively cheap where local industry by-products or consumer waste can be utilised. However, materials such as sewage and paper mill by-products need to be examined for suitability and subjected to quality controls to avoid introducing toxic compounds into the soil.

6.3.6. Physical Methods

6.3.6.1. Solarisation

Solarisation involves covering moist soil with thin, transparent plastic sheeting, for at least 4 weeks, to enhance the heat of the sun. In sunny regions it is used to control many soilborne pathogens and other soil pests effectively (FAO 1991). It pasteurises the soil rather than sterilising it, enhancing the activity of some beneficial microorganisms. The main disadvantages are the length of time for which the soil has to be covered, and, as with MB, the disposal of waste plastic sheeting. Solarisation is used on thousands of acres in diverse countries, including Egypt, Morocco, India, Pakistan, Jordan, Israel, Greece, Australia, and sunny regions of Japan and the USA (Katan & DeVay 1991). For a number of crops, solarisation needs to be combined with other practices to make it as effective as MB. Growers in a very intensive horticultural region of Italy, for example, successfully control pests using solarisation combined with IPM, and have found it cheaper than using MB (MBTOC 1994:100).

6.3.6.2. Steam Heating

Pasteurising soil with steam at a temperature of 70-80° C is as effective as MB under appropriate conditions (MBTOC 1994:76). It is particularly suitable for smaller areas such as glasshouses, shadehouses and nurseries. Steaming soil at about 80° C sterilises it, as MB does, and can result in a biological vacuum where pathogens are able to re-colonise the soil unless sanitary practices are strictly adhered to. Prolonged steam above 80° C can degrade soil structure and release undesirable compounds such as manganese. However, there are other steam treatments methods that avoid these problems (MBTOC 1994:76). Steam is used by growers in a wide range of countries.

The cost of purchasing steam boilers presents a cost barrier. However, a study in the UK found that if growers are able to hire boilers rather than purchase them the cost is similar to using MB (Ellis 1991:77). In some developing countries many tobacco growers already own boilers (for conditioning cured leaves), so a steam system such as negative pressure would be an option for tobacco seedbeds where the boiler is sufficiently close for delivering steam via pipes.

6.3.7. Chemical Treatments

Fumigants, such as methyl isothiocyanate (MITC), metam sodium, dazomet, chloropicrin, 1,3-dichloropropene (1,3-D) and ethylene dibromide (EDB) can be used to control some soil pests. These pesticides are not as effective as MB, and often need to be used in combination with other pesticides or other techniques.

Like MB, alternative chemical treatments can have negative impacts on soil, water or other aspects of the environment (Conway & Pretty 1991). Some are officially recognized as posing hazards to human health (WHO 1990). Metam sodium, for example, is classed as a teratogen and genotoxin; 1,3-D has been listed as a probable (B2) human carcinogen by the US Environmental Protection Agency (EPA 1992); while EDB has been banned in some countries because of groundwater contamination and carcinogenic hazards (MBTOC 1994:80,122-123).

TABLE 6.1
Examples of alternative methods of pest control used in developing countries.

Crop	Example of alternative pest control method	Example of country using method
Tobacco seedbeds	Soil substitute	Zimbabwe (trial)
	Nematicides such as 1,3-D with EDB or MITC	Zimbabwe
	Steam treatments	Thailand
	Solarisation, composting	China
Flowers, ornamentals	IPM, composting	Colombia
	Steam treatments	Thailand, Colombia
	Tagetes extract (nematodes)	Kenya (trial)
Banana	IPM	Costa Rica
	Dazomet [1]	Philippines
Broccoli	IPM	Guatemala
Cabbage	IPM	Taiwan, Malaysia, Sri Lanka, Philippines (trial)
Cumin	Solarisation, soil amendments	India
Mangoes	IPM	Pakistan
Pepper, sweet or chilli	IPM	Indonesia, Sri Lanka, Malaysia (trial)
Snowpeas	IPM	Guatemala
Strawberries	IPM	Zimbabwe, Guatemala
	Soil amendments (waste organic matter)	Senegal
	Metam sodium, other pesticides	South Africa
Tomatoes	IPM	Mexico, Guatemala
	Soil amendments	Senegal
	Solarisation	Morocco, Jordan
Nurseries	Steam	Zimbabwe
	Natural soil substitutes (bark)	Zimbabwe
Tree nurseries	IPM	China
Niche market organic produce	Methods complying with organic production standards	Mexico, Costa Rica, Bolivia El Salvador, Dominican Republic Burkino Faso, Egypt, Senegal, India, Indonesia, Myanmar
Various horticultural crops	Composting/IPM	Malaysia, Chile
	IPM	Vietnam, Indonesia
	Solarisation, or solarisation with IPM	India, Pakistan, Morocco, Jordan, Egypt

[1] *Dazomet does not control all the pests controlled by MB; however, it provides adequate control in certain situations.*

6.4. Examples of Successful Soil Alternatives

Table 6.1 presents some examples of developing countries and crops where alternatives are in use. The crops, pests, climates and circumstances covered by these alternatives are very diverse. They demonstrate that there is considerable scope for extending the use of soil alternatives to a wide range of situations. Some alternatives, such as the Colombia composting/IPM system, are used on a very wide scale. The following section gives some examples of alternatives in use. Most examples are drawn from industrialised countries, because this is where more studies are available, but are relevant to developing countries. MBTOC pointed out that effective alternatives are generally the same in developing countries as in industrialised countries. (The separate issue of resources and infrastructure is discussed in subsequent chapters.)

- **Composting/IPM for cut flowers**
  About 450 farms on an area of about 4,200 hectare in Colombia use a combination of sophisticated composting and IPM to control pests in their very successful cut flower export industry. Techniques include composting, hygienic measures, daily pest monitoring, limited crop rotation, resistant varieties, biological controls and selected pesticides. Spot steam treatments are used in production beds when necessary (Rodriguez-Kabana & Martinez-Ochoa 1995).

- **Solarisation/IPM for strawberries, tomatoes and vegetables**
  Growers in an intensive horticultural region of Italy, famous for its strawberries, are using a mix of solarisation and IPM techniques such as composting, cultivation techniques and selected use of pesticides. This gives equal yields (and sometimes higher yields) and costs much less than MB or steam (Correnti & Di Luzio 1994, MBTOC 1994, Vickers 1995). A combination of solarisation and IPM is also used successfully for tomatoes grown in plastic tunnels on about 50 hectares in another region of Italy (Vickers 1995).

- **IPM and other techniques for strawberries and vegetables**
  Open-field strawberry growers in Germany have replaced MB primarily with IPM, including pest resistant varieties and selected pesticides. MB has been phased out for all food crops, so the use of alternatives is widespread (Ketzis 1992).

- **IPM and pesticides for vineyards**
  More than half of the large area of commercial vineyards in California is treated with alternatives to MB. Alternatives are based on combinations of techniques including pest monitoring, cover crops, composting, subsoil ploughing and selected pesticides (MBTOC 1994).

- **Pesticides for open-field strawberries**
  Formerly dependent on MB, open-field strawberry production in parts of the Netherlands now uses alternative fumigants such as 1,3-D or metam sodium every 4 years. They also apply hygienic practices

Photo: Natalia Martinez-Ochoa

Sophisticated composting is an important component of the alternative IPM/composting system used in the cut flower industry in Colombia.

and selected pesticides. This combination is used on 1,950 hectares to produce 17,000 tonnes of open-field strawberries annually. Growers are moving to soil substrates (peat) to avoid using fumigants like 1,3-D and metam-sodium (De Barro 1995).

- **Cheap substrates for tomatoes**
Mixed substrates (eg. porous basalt, perlite, agilla) have had successful trials in Sicily for three years. They are used on 3.5 hectares, and the area is due to increase (Vickers 1995). Many cheap, clean waste materials can be used eg. grain hulls, coal grit, waste bark from forest industries; they can be sterilised with steam if necessary.

- **Composted bark substrates for nurseries**
Since the 1970s, compost and composted bark have replaced virtually all the MB used in the Ohio nursery industry, effectively controlling soil diseases for trees, flowers and vegetable nurseries (MBTOC 1994).

- **Peat substrates for covered strawberries**
Peat is used as a soil substitute on about 122 hectares to produce about 14,000 tonnes of strawberries annually in the Netherlands (De Barro 1995). The substrate allows double-cropping. Problem diseases such as Botrytis, Phytophthora and Verticillium are uncommon, but can be treated with specific fungicides if they arise. Some farmers also use substrates in plastic tunnels, which are cheaper to set up than glasshouses (De Barro 1995).

- **Substrates and steam for covered crops**
For greenhouse crops in Germany, alternatives that have replaced MB include steam, soil substitutes and IPM (Ketzis 1992). Alternatives adopted in Germany are generally less capital intensive than those adopted in glasshouses in the Netherlands.

- **Substrates and steam for propagation beds**
Cut flower growers in Colombia plant propagative material in mixed substrates (such as coal slag, rice hulls, charcoal, foam pellets) which are first sterilised with steam. Steam from fixed and mobile boilers is also used to sterilise the raised beds where mother stock plants are produced (Rodriguez-Kabana & Martinez-Ochoa 1995).

- **Steam treatments for covered crops**
Steam is an effective alternative used for many glasshouse crops in southern and northern Europe. It is frequently used for cut flowers in Italy (Gullino 1992). The traditional steam systems are expensive and energy-intensive, but new energy-efficient systems are now available.

- **Mixed techniques for forest nurseries**
A large commercial forest nursery in Florida has grown pine seedlings successfully without MB. The Florida Division of Forestry has also grown successful crops for two years without MB, saving taxpayers about $40,000 (fumigation costs). In the last 3 years five forest seedling crops have been successfully produced in Florida and South Carolina in soils which have not been fumigated for 5 years (Bernard 1995).

6.5. Crop Yields Using Alternatives

Some alternatives give lower yields than MB, while others give equal or higher yields. Clean substrates in particular tend to give significantly higher yields than using MB-treated soil. Experience shows that if alternatives are selected carefully, it is feasible to maintain or in some cases to increase yields (and profitability). Examples of equal or increased yields using alternatives:

- Strawberries grown in natural soil substitutes in Italy gave yields of 4.8 kg/m^2 compared to 3 kg/m^2 using soil treated with MB. It is common for soil substitutes to give strawberry yields 20% higher than MB (De Barro 1995; Nuyten 1995).
- Open-field strawberries produced using pesticides in the Netherlands give average yields of 3-4 kg/m^2 per crop, compared to 2 kg/m^2 for MB (De Barro 1995).
- Strawberries grown in peat substrate in the Netherlands: double-cropping on substrates gives an average yield of 9 kg/m^2, compared to 4 kg/m^2 using MB (De Barro 1995).
- Pepper crops produced in Italy using solarisation give yields 20% higher than using MB (Vickers 1995).
- Tomatoes grown on substrates (eg. porous basalt, perlite and argilla) in Sicily have had successful trials since the early 1990s. Yields and quality were found to be better than the standard system using MB (Vickers 1995).

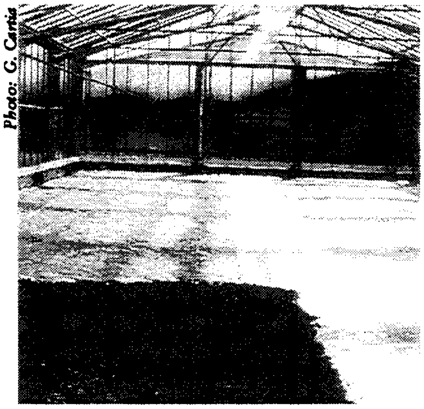


Photo: G. Castia

Solarisation is used in many countries to pasteurise the soil: the plastic sheets are laid over the soil to trap the sun's heat.

- Solarisation/IPM used for tomatoes grown in a region of Italy gives yields and quality equal to using MB. In some cases yields and profits are greater using the alternative (Vickers 1995).
- Trials on solarisation/metam sodium for tomatoes in Florida found that marketable yield was the same as using MB. Fusarium crown rot (incidence and severity) was also controlled equally by MB and the alternative (McGovern 1996).
- Modern solarisation techniques trialed on tomatoes in Florida gave yields equal to using MB (Chellemi et al 1995).
- Average yields of tomatoes in the Netherlands, where MB is no longer used for soil, are 520 tonnes per hectare. This compares with average yields of 518 tonnes per hectare in Belgium where many growers use MB (Kwantitatieve Informatie 1994/95, Ministry of Agriculture 1995).
- Melon yields in the Netherlands were doubled when MB was replaced with substrates, increasing from 10 kg/m^2 using MB to 20 kg/m^2 using the same variety of melon plants on rockwool (De Barro 1995).
- Covered cucumbers in the Netherlands gave yields of 26.6 kg/m^2 when grown on soil using MB. Steaming the soil gave the same yield as using MB. Rockwool substrates allowed a triple crop, giving yields of 67.9 kg/m^2 (De Barro 1995).

Table 6.2 shows tomato yields in various European countries, allowing comparison of high-yield systems (using substrates predominantly) and low-yield systems, and of countries using MB and alternatives. Germany and the Netherlands, which no longer use MB for food crops, have high yields compared to other countries with similar crop systems.

6.5.1. Importance of Production Systems

There is great diversity among agronomic systems that carry the same name. For example, there are ineffective IPM systems, steam treatments and MB applications, but there are also highly effective and cost-efficient versions of these systems. Likewise there are soil substitute systems that are poorly managed or designed, allowing development of diseases, as well as effective systems. Careful selection of alternative techniques is therefore essential. The existence of many cost-effective IPM systems established in developing countries, using cheap local materials and inputs, demonstrates that appropriate systems can be selected.

TABLE 6.2

Tomato yields from high-yield and low-yield systems, showing use of MB.

Country	Average crop yield 100 kg/ha (1992)	MB used in tomato sector
Countries using low-yield systems predominantly:		
Germany	640	No
Greece	514	Yes
Spain	476	Yes
France	670	Yes
Italy	465	Yes
Portugal	447	Yes
Countries using high-yield systems predominantly:		
Netherlands	4,332	No
Belgium	3,425	Yes
UK	2,600	Yes
Average for 12 European countries	559	

Source of data: Eurostat.

It should be noted that the use of MB (or any pest control system) is just one factor determining yields and marketable production. Substantial increases in horticultural production experienced in recent years in some developing countries are due to diverse factors, such as use of tunnels or greenhouses, higher yielding cultivars, irrigation, improved marketing, and improved distribution systems.

6.6. Soil Alternatives Relevant to Zimbabwe, Thailand and Chile

The estimated amount of MB used for soil (as a percentage of national consumption in 1994) was 85% in Zimbabwe, 5% in Thailand and 70% in Chile. Tables 6.3 - 6.5 summarise the alternatives relevant to the crops using MB in each of the three countries.

Alternatives are known to be in use in other countries for all the soil uses of MB, with the exception of golf courses. In fact, it is most likely that some countries currently use alternatives for golf courses, since MB cannot be used for this purpose in certain countries.

Examples of technically feasible alternatives are given for all soil uses, including golf courses, in the three countries.

Table 6.3
Soil alternatives relevant to Zimbabwe.

Percent of MB used in 1994	Crops using MB [1]	Examples of alternatives in use	Examples of technically feasible alternatives
83%	Tobacco seedbeds	• Steam treatments -Thailand • Hydroponics - USA	1. Permanent soil beds sterilised with steam 2. Beds using substrates and steam where necessary 3. Seed trays and substrates 4. Nematicides with other practices (see Table 3.4) 5. Fumigants with other practices
2%	Cut flowers	• IPM/compost/steam - Colombia • Peat Substrate - UK • Steam - Italy, UK Where climate & time allow: • Solarisation/nematicides - Italy	1. IPM/composting/steam 2. Clean substrates 3. Tagetes extract nematicide & other practices (see Table 3.5) 4. Fumigants with other practices 5. Where suitable, solarisation with IPM or other practices
<1%	Nurseries & Seedbeds	• Substrates/steam - Colombia, UK • Bark substrates - Zimbabwe, Ohio • Steam - Zimbabwe • Mixed techniques - Florida	1. Steam treatments 2. Clean substrates 3. Fumigants with selected pesticides 4. Where suitable, solarisation with other treatments

Table 6.4
Soil alternatives relevant to Chile.

Est. Percent of MB used in 1994	Crops using MB [1]	Examples of alternatives in use	Examples of technically feasible alternatives
49%	Tomato seedbeds under plastic To control mainly *Pyrenochaeta lycopersici* & other fungi	• Mixed substrates -Sicily • IPM - Mexico, Guatemala • Steam - Italy Where climate & time allow: • Solarisation/fumigant - Florida • Solarisation/IPM - Italy	1. IPM/composting/steam 2. Steam treatments 3. Clean substrates 4. Selected fungicides with treatments or practices to control other pests 5. Other fumigants with selected pesticides or practices 6. Where suitable, solarisation with IPM or other practices
8%	Fresh pepper seedbeds under plastic To control mainly *Pyrenochaeta* & other fungi	• IPM - Indonesia, Sri Lanka Where climate & time allow: • Solarisation/IPM - Italy	1. IPM/composting/steam 2. Steam 3. Clean substrates 4. Fungicides with other treatments or practices 5. Fumigants with selected pesticides or practices 6. Where suitable, solarisation with IPM or other practices
6%	Processed tomato seedbeds	• Substrates/steam for other types of seedbeds - Colombia, UK	1. IPM/composting/steam 2. Steam 3. Clean substrates 4. Fungicides with other treatments or practices 5. Fumigants with selected pesticides or practices 6. Where suitable, solarisation with IPM or other practices

(chart continued on next page)

TABLE 6.4 (CONTINUED)
Soil alternatives relevant to Chile.

Est. Percent of MB used in 1994	Crops using MB [1]	Examples of alternatives in use	Examples of technically feasible alternatives
3%	Tobacco seedbeds	• Steam treatments - Thailand • Hydrophonics - USA	1. Steam 2. Clean substrates 3. Fumigants with selected pesticides or practices (see Table 3.4) 4. Where suitable, solarisation with IPM or other treatments
2%	Pepper seeds grown under plastic	• See alternatives used for sterile seedbeds in general	1. Steam 2. Clean substrates 3. Fumigants with selected pesticides or practices (see Table 3.4) 4. Where suitable, solarisation with other treatments
<1%	Fruit & nut tree nurseries seedbeds To control mainly *Armillaria* fungi	• Substrates- Ohio • IPM and pesticides - California	1. Steam 2. Clean substrates 3. Fumigants with selected pesticides 4. Where suitable, solarisation with other treatments
<1%	Other vegetables: seedbeds for lettuce, eggplant, onions etc.	• Steam - Germany, Netherlands, UK • Substrates - Germany, Netherlands • IPM - Germany, Vietnam, Indonesia	1. IPM/composting/steam 2. Steam 3. Clean substrates 4. Selected fungicides with other treatments or practices 5. Fumigants with selected pesticides or practices 6. Where suitible, solarisation with other treatment
<1%	Forest tree nurseries plastic To control mainly *Macrophomina phaseolins* Fungus	• Mixed techniques - Florida, Carolina USA • IPM - China • Composted bark - Ohio	1. Steam 2. Clean substrates 3. Fumigants with selected pesticides (see Table 3.4) 4. Where suitable, solarisation with other treatments
<1%	Nurseries & seedbeds	• Substrates/steam - Colombia, UK • Bark substrates - Zimbabwe, Ohio • Steam - Zimbabwe • Mixed techniques - Florida, Carolina	1. Steam 2. Clean substrates 3. Fumigants with selected pesticides 4. Where suitable, solarisation with other treatments

[1] *In these crops the main targets of MB fumigation are various species of fungi.*

TABLE 6.5
Soil alternatives relevant to Thailand.

Percent of MB used in 1994	Crops using MB	Examples of alternatives in use	Examples of technically feasible alternatives
5%	Tobacco seedbeds To control *Pythium, Rhizoctonia, Meloidogyne* etc.	• Steam treatments -Thailand • Hydroponics - USA	1. Steam treatments 2. Clean substrates 3. Fumigants or nematicides with selected pesticides or practices (see Table 4.7) 4. Where suitable, solarisation with other treatments
	Golf courses		1. Steam 2. Other fumigants with selected pesticides
	Nurseries: flowers and coffee	• Substrates/steam - Colombia, UK • Bark substrates - Zimbabwe, Ohio • Steam - Zimbabwe • Mixed techniques - Florida	1. Steam 2. Clean substrates 3. Fumigants with selected pesticides 4. Where suitable, solarisation with other treatments

6.7. Alternatives for Stored Products

6.7.1. Techniques Identified by MBTOC

Existing and potential alternative treatments for stored products, such as grains, have been identified by MBTOC and include (MBTOC 1994):

- improved hygiene (an important practice but not sufficient on its own);
- cold treatments;
- heat treatments;
- carbon dioxide treatments;
- nitrogen treatments;
- biological controls (need to be used with other treatments);
- insect growth regulators (need to be used with other treatments);
- inert dusts;
- insecticides;
- phosphine and other fumigants; and
- irradiation.

MBTOC notes that in some cases alternatives have to be based on combinations of treatments or practices. Good hygienic practices to prevent grains from becoming infested with insects are important in reducing the need for treatments.

6.7.2. Examples of Effective Alternatives for Stored Products

Alternatives are known to be in use for stored products in diverse climates and conditions. Phosphine, in particular, is widely used. Table 6.6 gives examples of alternative treatments used for stored products in various countries.

TABLE 6.6

Examples of alternatives used for stored products. Some examples of successful trials are also included.

Stored products	Examples of alternative treatments	Examples of countries using alternatives
Stored grains, pulses	Phosphine	Zimbabwe, Thailand, Vietnam, Indonesia, Philippines, Malaysia, Germany and many other countries
	Carbon dioxide	Indonesia, Philippines, Vietnam, Australia
	Nitrogen	Germany
	Nitrogen-flushed retail packs	Thailand (commercial trial)
	Hermetic storage	Israel, Philippines Argentina (trial)
	Vacuum chamber	Indonesia
	Heat treatment	Australia (prototype)
	Freezing	Europe (for premium grains)
	Inert dusts (where appropriate)	Australia, Canada
Wooden items	Carbon dioxide	Germany
	Heat treatment	Denmark
	Nitrogen	Germany
Artifacts, museum items	Heat treatment with controlled humidity	UK, Germany, Austria
	Nitrogen flow	Germany

6.7.3. Alternatives for Stored Products Relevant to Zimbabwe, Thailand & Chile

The estimated amount of MB used for stored products in 1994 (as a percentage of national consumption) was about 13% in Zimbabwe (or higher in some years), about 23% in Thailand and zero in Chile. Table 6.7 presents technically feasible alternatives for the stored products using MB in the three countries. The only situation where these alternatives would not be feasible is where treatments have to be conducted very rapidly. However, grains in storage do not normally have to be treated rapidly. In instances where grains must be treated quickly, heat treatments would provide a faster treatment than MB. (The economics of the alternatives are discussed in Chapter 7).

TABLE 6.7

Alternatives for stored products relevant to Zimbabwe, Thailand and Chile.

Stored products (% of national MB consumption in 1994)	Examples of alternatives in use	Examples of technically feasible alternatives
Stored grains in: • Zimbabwe (13% of national MB consumption, or more in some years) • Thailand (23% of national MB consumption)	• Phosphine - Zimbabwe, Thailand, Philippines • Carbon dioxide - Indonesia • Retail packs flushed with carbon dioxide - Thailand • Hermetic storage - Philippines, Israel	1. Carbon dioxide 2. Hermetic storage with other treatment 3. Nitrogen 4. Phosphine 5. Heat treatment for some grains 6. Retail packs flushed with carbon dioxide, in situations where y grain would be packaged anywa 7. Inert dusts, where appropriate 8. Grain protectants and insect growth regulators 9. Insecticides

6.8. Alternatives for Durable Exports and Imports

Durable commodities treated with MB are predominantly grains, but also include pulses, spices, nuts, cocoa beans, tobacco, timber, wooden items and handicrafts. MB is applied to import/export commodities for three main purposes:

1. **Quarantine treatments** - required by official quarantine authorities to prevent the introduction or spread of quarantine pests and diseases.

2. **Pre-shipment treatments** - applied directly preceding and in relation to export, to meet the phytosanitary or sanitary requirements of importing countries or existing requirements of exporting countries, as defined under the Montreal Protocol (Decision VI/5, UNEP 1995b:25).

3. **Commercial treatments** - carried out at the request of a trader or importing company, often specified in a commercial contract or letter of credit as a pre-requisite for receiving payment for exported goods. The treatment reduces commodity losses and damage from pests.

When conducting surveys to determine the quantity of MB used, we found it was not always possible to distinguish between treatments required by official quarantine authorities and treatments required by commercial companies, because exporters themselves sometimes did not know whether the importing company or authorities were responsible for the requirement. However, in Thailand a large proportion of the MB used for export grains is for meeting the commercial contracts (letters of credit) of importers; it is frequently not for official quarantine purposes.

6.8.1. Alternatives for Durable Commodities Identified by MBTOC

The disinfestation treatments (ie. those that kill pests rather than limiting their numbers) identified in the stored products section above would be technically feasible for quarantine, pre-shipment or other commercial export requirements. Examples of relevant export/import treatments identified by MBTOC are:

- phosphine;
- carbon dioxide (used in transit for rapid treatment);
- nitrogen, in some cases;
- heat treatments for certain grains; and
- irradiation.

6.8.2. Examples of Alternatives Used for Durable Commodities

Table 6.8 presents examples of alternatives used for exported or imported durable commodities, in various countries. Most of these treatments kill pests completely (rather than just reducing their numbers), so would be effective as quarantine treatments, provided official authorities were to accept their use. Tables 6.9 and 6.10 present examples of quarantine treatments approved by the US Department of Agriculture's (USDA) Animal & Plant Health Inspection Service (APHIS) for durable commodities. The diversity of treatments and commodities shows that there is great potential for applying approved treatments to a wide range of other commodities.

Table 6.8

Examples of alternative treatments used for durable export/import commodities.

Commodity	Example of alternative treatment	Example of country
Grain, nuts and similar edible exports or imports	Phosphine	Germany, UK, Thailand
	Carbon dioxide retail packs	Thailand
	In-transit carbon dioxide treatment	Australia (groundnuts)
	Nitrogen	Australia, Thailand (for premium rice)
Black pepper	Phosphine	Malaysia
Cocoa beans	Phosphine	Malaysia and many other countries
Coconut products	Phosphine	Philippines
Coffee	Phosphine	Vietnam
Spices	Phosphine	Malaysia
Seeds of cotton, cover crops, castor	Phosphine	Philippines
Tobacco	Phosphine	Philippines, Indonesia.
Basketware, handicrafts, accessories	Phosphine	Philippines
Wood products eg. rubberwood furniture	Phosphine	Malaysia, Philippines (for exports to Japan, USA), Vietnam
Sawn timber	Chemical dip (wood preservative)	Malaysia
Logs	Sulphuryl fluoride	USA
	Water immersion and insecticide	Japan
Various durable commodities	Phosphine	Philippines

TABLE 6.9

Examples of cold and heat treatments approved by the USA quarantine authorities (USDA-APHIS) as quarantine treatments for durable commodities.

Type of treatment and examples of commodities		Duration and treatment
Heat Treatments	• Any durable commodity that can tolerate heat - to control Khapra beetle	7 minutes at 150°F
	• Feeds & milled products for processing	7 minutes at 150°F
	• Bagasse/sugarcane	2 hours at 158°F
	• Bags for seeds	1 hour at 212°F
	• Lumber (3" thick) with wood borers	14 hours at 130°F or 7 hours at 140°F
	• Corn (maize) ears not for propagation	2 hours at 168°F
	• Rice straw novelties and articles	2 hours at 180°F
	• Niger seeds with Khapra beetle or soil	15 minutes at 212°F
Steam Treatments	• Niger seeds with Khapra beetle or soil	15 minutes at 212°F
	• Seeds not for propagation	to 212°F
Steam Treatment With Pressure	• Rice straw and hulls, straw mats	30 minutes
	• Rice straw novelties	30 minutes
	• Novelties and articles from broomcorn	30 minutes
Vacuum Steam Flow Process	• Leaf tobacco for export	15 minutes at 170°F
	• Blended strip tobacco for export	3 minutes at 160°F
Hot Water Dips	• Bulbs with *Ditylenchus* nematodes	2 hours at 75°F & 4 hours at 110°F
	• Lily bulbs with *Aphelenchoides* nematodes	- at 102°F
	• Senecio with *Aphelenchoides* nematodes	1 hour at 110°F
	• Narcissus bulbs with bulb scale mite	1 hour at 110°F
	• Certain tubers with *Meloidogyne* spp.	30 minutes at 118°F
	• Horseradish root with golden nematode	30 minutes at 118°F
	• Banana roots	30 minutes at 110°F & 60 mins at 120°F
	• Sugarcane	4 hours at 110°F
	• More than 17 other hot water treatment schedules	
Freezing Treatments	• Items with insects in soil	5 days at 0°F

Source: Compiled from USDA-APHIS 1993 'Plant Protection and Quarantine Treatment Manual', revised edition, Hyattsville.

TABLE 6.10

Examples of fumigants and fungicide treatments approved by the USA quarantine authorities (USDA-APHIS) as quarantine treatments for durable commodities.

Type of treatment and examples of commodities		Duration and treatment
Fumigants	• Tobacco for export	96 hours phosphine
	• Cotton, cottonwaste and cotton products in bulk, against boll weevil etc.	120 hours phosphine
	• Seeds of cotton, packaged or bulk	120 hours phosphine
	• Seeds & dried pods, okra, kenaf, etc.	120 hours phosphine
	• Bales of hay	72 hours phosphine
	• Wooden items with wood borers	72 hours phosphine
	• Non-plant articles infested with ticks	24 hours carboxide
	• Non-plant articles infested with ticks	24 hours sulphuryl fluoride
	• Wooden items with wood borers	24 hours sulphuryl fluoride
	• Wood products, containers with termites	24 hours sulphuryl fluoride
Fungicides	• Seeds of corn Medicago spp. from Europe	apply thiram
	• Seeds for propagation, small batches	apply zineb and captan
	• Seeds of sugarcane	30 minutes sodium hypochlorite, then 8 hours drying
	• Seeds of citrus	2 minutes sodium hypochlorite, dry

Source: Compiled from USDA/APHIS 1993 'Plant Protection and Quarantine Treatment Manual', revised edition, Hyattsville.

6.8.3 ALTERNATIVES FOR DURABLE COMMODITIES RELEVANT TO ZIMBABWE, THAILAND AND CHILE

Durable export/import commodities accounted for <3% of MB used in Zimbabwe, about 70% of MB used in Thailand, and approximately 6% in Chile, in 1994. Tables 6.11 - 6.13 identify alternatives that are relevant to the durable export/import commodities treated with MB in the three countries. In each case there are alternatives in use or registered as quarantine treatments, as well as potential alternatives. Some changes in infrastructure and commodity management would be necessary to introduce alternatives, particularly where MB treatments are carried out rapidly. Rapid alternative treatments are used in a few countries, but would require further development and investment to meet commercial needs in the three countries.

Alternatives for officially-required quarantine treatments, while technically feasible, would require approval by the relevant authorities. The main barriers would be the cost of demonstration trials and of negotiations with quarantine authorities.

TABLE 6.11
Alternatives for durable export/import commodities relevant to Zimbabwe.

% of national MB consumption in 1994	Commodities treated with	Examples of alternatives in use or registered	Examples of technically feasible alternatives
small %	Grain exports	• Phosphine - many countries • Retail packs flushed with carbon dioxide - Thailand • Heat treatment - quarantine treatment approved by USA for any durables that tolerate heat	1. In-transit carbon dioxide 2. Phosphine 3. Retail packs flushed with carbon dioxide 4. Heat treatment in some 4. Heat treatment in some cases 5. Nitrogen in some cases
<1%	Tobacco exports -MB required by Japan & Taiwan mainly	• Phosphine - Zimbabwe • Vacuum steam flow process - quarantine treatment approved by USA	1. Phosphine 2. Carbon dioxide 3. Vacuum steam flow process 4. Pre-shipment inspection and certification 5. Methoprene insect growth regulator
<1%	Curios & artifact exports	• Heat treatment with constant humidity - UK, Germany, Austria • Heat treatment - quarantine treatment approved by USA to kill Khapra beetle • Phosphine for artifacts free from metal components -Philippines	1. Heat treatment with constant humidity 2. Nitrogen flow fumigation 3. Carbon dioxide treatment in some cases 4. Phosphine for artifacts free from metal components

TABLE 6.12
Alternatives for durable export/import commodities relevant to Chile.

Commodities treated with MB	Examples of alternatives in use or registered	Examples of technically feasible alternatives
Timber exports (about 6% of national MB consumption)	• Sulphuryl fluoride -USA • Heat treatment -quarantine treatment approved by USA for sawn timber • Borate dip-diffusion treatment - registered in USA and Japan • Debarking • Processing timber prior to export	1. Conversion of logs to timber in Chile, prior to export 2. Sulphuryl flouride 3. Phosphine 4. Borate dip-diffusion treatment 5. Heat treatment in some cases

TABLE 6.13
Alternatives for durable export/import commodities relevant to Thailand.

Commodities treated with MB	Examples of alternatives in use or registered	Examples of technically feasible alternatives
Grain exports (70% of national MB consumption)	• Phosphine - many countries • Retail packs flushed with carbon dioxide - Thailand • In-transit carbon dioxide - Australia • Heat treatment - quarantine treatment approved by USA for durables that tolerate heat	1. In-transit carbon dioxide 2. Phosphine 3. Retail packs flushed with carbon dioxide 4. Heat treatment in some cases 5. Nitrogen in some cases 6. In-transit phosphine in some cases

6.9. *Alternatives for Perishable Exports and Imports*

6.9.1. Alternatives Identified by MBTOC

Perishable commodities include fresh fruit, fresh vegetables and cut flowers. MBTOC pointed out that quarantine alternatives for perishable commodities sometimes have to be based on more than one treatment or procedure. Techniques include:

- systems approach: series of cultural practices which each reduce pest levels;
- pest-free zones and pest-free periods;
- inspection and certification prior to export;
- cold treatments;
- heat treatments (eg. hot dry air, hot moist air, hot water dip);
- controlled atmospheres (eg. very low oxygen, high carbon dioxide or nitrogen)
- modified atmospheres;
- physical removal of pests;
- microwaves;
- irradiation (generally makes pests sterile rather than killing them);
- other fumigants; and
- insecticides.

Of the many perishable commodities treated with MB, MBTOC identified only five commodity/pest combinations where there are as yet no approved alternative techniques:

1. grapes from Chile to USA (infested with *Brevipalpus chilensis* mite);
2. apples infested with codling moth - to countries where it is absent;
3. stonefruit infested with codling moth;
4. certain berryfruit; and
5. certain root crops;

MBTOC noted that there are potential alternatives for these five commodities (MBTOC 1994:226).

6.9.2. Examples of Approved Quarantine Treatments for Perishable Commodities

Table 6.14 gives examples of perishable commodities where alternative quarantine treatments have been approved. Table 6.15 shows the number of known cases where quarantine treatments based on alternative techniques (for perishable commodities) have been approved by quarantine authorities.

Many fruits, vegetables and cut flowers do not require any quarantine treatment. Quarantine treatments are generally applied in the importing country if pests of concern are detected. However, in certain cases an importing country requires a treatment prior to export and in a few cases the use of MB is specified.

TABLE 6.14

Alternative quarantine techniques, with examples of approved applications for fresh fruit, vegetables and cut flowers.

Procedure or treatment	Examples of approved quarantine applications
Cold treatments	• Grapes & kiwifruit from Chile to Japan • Citrus from Israel, South Africa, Florida (USA) to Japan • Cherries from Chile to USA • Apples from Chile, Mexico, Israel, Italy, France, Spain, South Africa to USA • Citrus from 23 countries to USA • Peaches, apricots & plums from Morocco to USA
Heat treatments	• Mangoes from Taiwan to Japan • Papaya from Hawaii to Japan and USA • Narcissus bulbs to Japan and USA • Tomatoes, zuccini, squash, eggplant, bell peppers to USA
Certified pest-free zones or pest-free periods	• Melons from a region of China to Japan • Squash from Tasmania to Japan • Cucurbits to Japan and USA • Nectarines from USA to New Zealand
Systems approach (IPM)	• Immature banana to Japan • Avocado
Pre-shipment inspection and certification	• Certain cut flowers from Netherlands to Japan • Apples from Chile and New Zealand to USA • Nectarines from New Zealand to Australia • Green vegetables to many countries
Physical removal of pests	• Root crops are accepted by many countries if all soil is removed • Hand removal of certain pests from cut flowers to USA
Controlled atmospheres	• Apples from Canada to California
Pesticides, fumigants, aerosols	• Cut flowers from New Zealand to Japan • Asparagus to Japan • Tomatoes from Australia to New Zealand • Cut flowers from Thailand and Hawaii • Bulbs to Japan
Combination treatments	• Soapy water and wax coating for cherimoya from Chile to USA • Vapour heat and cold treatment for lychees from Taiwan to Japan • Pressure water spray and insecticide for certain cut flowers to USA

Source: Compiled from MBTOC 1994:222-226.

6.9.3 Alternatives for Perishable Commodities Relevant to Zimbabwe, Thailand and Chile

Quarantine treatments for perishable commodities account for <1% of MB used in Zimbabwe, 1% in Thailand and 22% in Chile. Approximately 20% of the MB used in Chile is used solely for grapes exported to the USA. Potential alternatives were identified for each commodity (Tables 6.17 - 6.19).

Resources would be required for development of the alternatives. In the case of flower exports from Zimbabwe, for example, alternatives are available for surface pests, but research work would be required to develop a suitable treatment for Western Flower Thrips. Where an importing country requires MB treatment prior to export, alternatives will have to be approved by quarantine authorities of importing countries on a case-by-case basis. Negotiations can be extremely slow in this area, so it is likely to take a number of years to gain approvals.

Table 6.15

Number of known cases where countries have approved an alternative quarantine technique for perishable commodities (or groups of similar commodities).

Alternative procedure or technique	Number of cases where a country has approved an alternative quarantine treatment
Cultural practices	2 cases
Pest-free zones or periods	6 cases
Pre-shipment inspection	many cases
Cold treatments	61 cases
Heat treatments	11 cases
Controlled atmospheres	1 case
Modified atmospheres	nil cases
Physical removal of pests	many cases
Combined treatments	4 cases
Fumigants other than MB	5 cases
Chemical dips	3 cases

Source: Compiled from MBTOC 1994.

Table 6.16

Alternatives for perishable commodities relevant to Zimbabwe.

Commodities treated with MB - for quarantine	Examples of alternatives in use or registered for quarantine	Examples of technically feasible alternatives
Cut flowers (<1% of national MB consumption)	• Pre-shipment inspection & certification for surface pests - quarantine procedure used by many countries • Pressure water spray and insecticide dip for certain pests - USA	1. Improved pest control in field, followed by controlled atmosphere treatment during transit 2. Improved pest control in field, followed by double post-harvest treatment eg. double insecticide dip
Fruit & vegetable exports (<1% of MB consumption)	• Pre-shipment certification • Cold treatments • Heat treatments • Combined treatments • Pest-free zones	1. Cold treatments 2. In-transit controlled atmosphere treatments 3. Systems approach 4. Combined treatments

TABLE 6.17
Alternatives for perishable commodities relevant to Chile.

Commodities treated with MB - for quarantine	**Examples of alternatives in use or registered**	**Examples of technically feasible alternatives**
Grape exports to USA - to control *Brevipalpus chilensis* (c.20% national MB consumption)		1. Potential: treatment of vineyards to provide certified pest-free zones 2. Combined treatment: cold treatment combined with another treatment
Citrus fruit exports (<1% MB consumption)	• Cold treatments - quarantine treatment commonly used for citrus, eg. used by 23 countries exporting to USA • Heated dry air or heated moist air - quarantine treatments approved by USA for Mexican fruit fly	1. Cold treatment (sometimes with warm temperature pre-conditioning) 2. Heated dry air or heated moist air 3. Waxing
Stonefruit exports - nectarines, peaches, plums, apricots (<1% MB consumption)	• Inspection - quarantine procedure commonly used by USA for products from Chile and many countries • Cold treatment - quarantine treatment approved by USA for Moroccan imports	1. Improved pest control systems in field, followed by pre-shipment inspection and certification 2. Combination treatment
Tomato exports to Argentina (<1% MB consumption)	• Heat treatment - quarantine treatment approved by USA for various pests • Chemical dip - quarantine treatment approved by New Zealand for Australian exports	1. Vapour heat treatments 2. Chemical dip
Asparagus exports - treated to reduce chance of rejection in USA	• Chemical treatment - quarantine treatment approved by Japan	1. Chemical treatment 2. Double treatment
Strawberries and raspberries -treated to reduce chance of rejection in USA (<1% MB consumption)	• Inspection - used in many countries • Carbon dioxide treatment - used in USA	1. Cold or heat treatments, depending on pests 2. Carbon dioxide treatment in some cases 3. Sulphur dioxide treatment in some cases

TABLE 6.18
Alternatives for perishable commodities relevant to Thailand.

Commodities treated with MB - for	**Examples of alternatives in use**	**Examples of Technically feasible alternatives**
Orchid flower exports - to control *Dichromotrips corbetti* mainly (<1% of national MB consumption)	• Pre-shipment inspection and inspection and certification for surface pests only - quarantine procedure used by many countries • Hand removal of surface pests -quarantine treatment approved by USA • Chemical sprays or dips - quarantine treatments used by Thailand, Hawaii and New Zealand • Pressure water spray and insecticide for certain cut flowers - approved by USA	1. Improved pest control in field, followed by controlled atmosphere 2. Improved pest control in field, followed by double post-harvest treatment eg. double insecticide dip 3. Chemical aerosols for surface pests 4. Chemical dips in some cases
Ginger exports (<1% MB consumption)	• Removal of soil prior to export - quarantine treatment used by many countries • Heat treatment - quarantine treatment approved for bulbs by Japan and USA	1. Removal of soil 2. Cold treatment (possibly combined with other treatment) 3. Controlled atmosphere treatment
Asparagus exports - to control *Thrips tabaci* mainly (<1% MB consumption)	• Pre-shipment inspection and certification • Fumigation - quarantine treatment approved by Japan • Controlled atmosphere - used for US military supplies	1. Pre-shipment inspection and certification 2. Controlled atmosphere treatment 3. Combined treatment

CHAPTER 7

Economic Issues

THIS CHAPTER GIVES EXAMPLES OF THE COSTS OF USING ALTERNATIVES COMPARED TO USING METHYL BROMIDE (MB). INFORMATION OF THE PROFITABILITY OF DIFFERENT SYSTEMS IS PRESENTED WHERE AVAILABLE. SUBSEQUENT SECTIONS IDENTIFY THE GENERAL RESOURCES THAT WOULD BE REQUIRED TO REPLACE MB AND POTENTIAL SOURCES OF FINANCIAL ASSISTANCE. THE CHAPTER OUTLINES THE EXTERNALISED COSTS RESULTING FROM USE OF MB AND PRESENTS A COST-BENEFIT OVERVIEW. IT IDENTIFIES A NUMBER OF COMMERCIAL AND EMPLOYMENT OPPORTUNITIES ARISING FROM REDUCED USE OF MB.

7.1. Cost of Using Alternatives

This study has compiled some case studies of the operating costs of MB and alternatives in Zimbabwe and Chile. Data on comparative costs in other countries have also been summarised. These examples should be taken as approximate indicators of cost because actual costs will vary from one location or situation to another. Due to factors such as marketing policies and currency conversion, the cost of using MB itself varies from one country to another. It is therefore more meaningful to compare the relative costs of MB and the alternative, rather than absolute costs.

It is important to note that alternatives covered by the same name are often very diverse. For example, the term 'steam treatment' or 'IPM' covers many different practices, with different cost implications.

7.2. *Examples of Costs of Solarisation in Chile, Brazil Italy and Florida*

7.2.1. Soil Solarisation in Chile

A cost assessment conducted for this study estimated that MB costs on average US$3,620 per hectare in Chile, compared to about US$4,100 for solarisation (Rojas 1995) (see Table 7.1). For certain crops there would be an economic penalty from not using lands during summer, amounting to additional costs of approximately US$750 per hectare. Solarisation is rarely used in Chile. Producers combine it with chemical treatments (eg. dazomet) to increase efficacy and reduce chemical doses. New experiments with solarisation alone will be made in 1995/96. There are opportunities for reducing costs and increasing efficacy by combining solarisation with IPM - a combination used successfully in Italy (see Section 7.6).

Table 7.1

Cost of using MB compared to a solarisation technique in Chile.

Inputs	MB cost (US$/ha)	Solarisation cost (US$/ha)
Soil preparation	236	236
Chemical product	180	0
Tractor with driver	75	75
Machine application	105	105
Plastic (0.1mm)	2,625	2,625
Sowing by machine	250	250
Irrigation labour	0	63
Labour	150	750
Total	**3,621**	**4,104**

Source: Francisco J Rojas, ETEC, Santiago, 1995.

7.2.2. Solarisation in Brazil, Italy and Florida

Data collected for a UNDP study found the material cost of MB for tobacco seedlings in nursery operations in Brazil is US$29 per hectare (0.8% of the total production costs). Solarisation materials cost US$25 per hectare (0.7% of total production costs) (UNDP 1995).

The cost of using solarisation for tomatoes in the Ragusa region of Italy is about US$1,260 per hectare compared to about US$3,780 per hectare for using MB (Vickers 1995).

Studies conducted on autumn (fall) production of fresh tomatoes by the University of Florida in 1994 used a solarisation technique that gave tomato yields equal to using MB/chloropicrin. Solarisation was found to be fully compatible with standard production practices and resulted in savings of more than US$250 per acre when compared to the cost of using MB/chloropicrin (Chellemi et al 1995). Studies will continue with the aim of further improving the performance of solarisation and other alternatives.

7.2.3. Summary of Examples of Solarisation Costs

There is great diversity in solarisation techniques, and the examples of costs show similar diversity. For the cases where we were able to find comparisons of solarisation and MB costs, solarisation was cheaper in three out of four cases (Table 7.2). At one end of the spectrum MB was 12% cheaper than the alternative, and at the other end of the spectrum solarisation was 67% cheaper than using MB.

TABLE 7.2
Summary of available examples of soil solarisation costs.

Example of alternative	Cost of MB (US$)	Cost of alternative example	Cost comparison
Solarisation, Chile	$ 3,621 per ha	$ 4,104 per ha	MB 12% cheaper
Solarisation, Brazil	$ 29 per ha for material 0.8% of production costs	$ 25 per ha for materials 0.7% of production costs	Solarisation 14% cheaper
Solarisation, Italy	$ 3,780 per ha	c.$ 1,260 per ha	Solarisation 67% % cheaper
Solarisation, Florida	n/a	$250 per acre less than using MB	Solarisation $250 cheaper per acre

7.3. Examples of Costs of Steam Treatments

7.3.1. Steam Treatment in Chile

A cost assessment carried out for this project estimated that a steam technique in Chile would cost about US$13,971 per hectare, which is about 286% more than the cost of using MB (Rojas 1995) (see Table 7.3). Steam treatment in Chile is very expensive compared to steam systems in use in other countries, and farmers are not generally familiar with the cheaper techniques. The technique in Chile involves moving large quantities of earth into piles no more than 3 cubic meters. The cost of earth moving accounts for US$10,725, which is 77% of the cost. It would be feasible to apply steam systems that avoid the need to move soil, substantially reducing the cost for glasshouse and nurseries in particular. Steam is widely used for beds in the flower industry in Colombia, as part of a cost-effective production system (see Section 7.6).

TABLE 7.3
Cost of using MB compared to a specific steam technique in Chile.

Inputs	MB cost (US$/ha)	Steam cost (US$/ha)
Soil preparation	236	236
Chemical product	180	0
Steam production	0	2,289
Moving earth	0	10,500
Fertilization	0	146
Plastic (0.1mm)	2,625	75
Earth levelling	0	225
Sowing by machine	250	250
Labour, tractor application	330	250
Total	**3,621**	**13,971**

Source: Francisco J Rojas, ETEC, Santiago, 1995.

7.3.2. Steam Treatments for Tobacco in Brazil

Cost comparisons made for a UNDP study found that the material cost of steam is US$45.60 per hectare (1.3% of total production costs) for nursery tobacco seedlings in Brazil, while the material cost of MB is US$29.00 per hectare (0.8% of total production costs) (UNEP 1995). The cost of labour and other operational expenditure was assumed to be approximately the same according to this study.

7.3.3. STEAM TREATMENTS FOR STERILE BEDS IN COLOMBIA

The Colombia cut flower industry uses steam for cleaning propagation beds (raised beds for mother plants), and for occasional spot treatments in flower production beds. The approximate cost of using steam is US$18,519 per hectare (full production costs including labour etc.), compared to US$4,932 per hectare for using MB once per year (Rodriguez-Kabana & Martinez-Ochoa 1995). The actual cost of steam varies greatly according to the type of boiler and fuel used. The cost of steaming is more than three times greater than using MB in this example. However, because of the importance of obtaining disease and pest-free propagation material, steam is preferred over the other methods in the Colombian cut flower industry; steaming is considered the most reliable method (UNDP 1995).

7.3.4. STEAM TREATMENTS IN UK

The costs of five different steam systems in the UK have been compared in a detailed study (Ellis 1991). The report concluded that sheet steaming or hood steaming are comparable in cost to using MB if a suitable steam boiler can be hired rather than purchased (Ellis 1991:77). The negative pressure or Fink systems are competitive if deep steaming is required or sterilisation is carried out less frequently. Table 7.4 presents the cost details.

TABLE 7.4
Comparative inputs and costs for various steam treatments in the UK (US$ per 2,000 m²).

	Sheet - 200 mm depth	Sheet - 300 mm depth	Hood	Negative pressure	Fink
Boiler kg/h	1,000	1,000	1,000	1,000	1,000
Sheet size m2	100	100	20	67	67
Depth mm	200	300	150	500	500
Time per sheet h	4	8	0.25	5	5
Total time h	80	160	25	150	150
Energy used MJ	200,000	400,000	92,000	230,000	230,000
Fuel cost US$	945	1,890	435	1,086	1,086
Boiler US$	22,500	22,500	22,500	22,500	22,500
Annual cost US$	3,848	3,848	3,848	3,848	3,848
Boiler hire US$	960	1,920	300	1,800	1,800
Equipment US$	450	450	5,250	10,500	5,250
Annual cost US$	197	197	1,046	2,093	1,046
Labour hours h	80	160	25	150	150
Labour cost US$	540	1,080	170	1,013	1,013
TOTAL COST					
Boiler owned	5,531	7,014	5,498	8,039	6,993
Boiler hired	2,642	5,087	1,950	5,991	4,946

Source: Ellis 1991:68.

7.3.5. Steam Treatments in the Netherlands

A number of developments in the Netherlands and Germany have improved the fuel efficiency and reduced the time of operation of steam treatments, because steam is more widely used in those countries. Negative pressure steaming used for up to 10% of cucurbit production in the Netherlands costs US\$1.43 -1.74 per m² compared to about US\$1.66 per m² for MB. Using steam avoids the cost of leaching with water after MB fumigation (to reduce bromine residues) and allows faster replanting. Cucumbers grown on soil treated with steam give an average profit of US\$6.03/m², which is similar to the profit of US\$6.00/m² using MB (De Barro 1995).

7.3.6. Summary of Examples of Steam Costs

Diversity among steam techniques and costs is much greater than among solarisation techniques. As a generalisation, MB is cheaper than steam treatments, and in some cases considerably (at least 74%) cheaper (see Table 7.5). However, a few steam systems are cheaper or the same cost as MB, notably some negative pressure techniques, and certain techniques using boilers that are hired rather than purchased. Interestingly, some very expensive steam systems -almost four times the cost of MB - are used in Colombia in preference to MB because growers consider them to perform better (UNDP 1995).

Table 7.5
Summary of examples of various steam treatment costs.

Example of alternative	Cost of MB (US\$)	Cost of alternative example (US\$)	Cost comparison
Moving earth for steaming, Chile	\$ 3,621 per ha	\$ 13,971 per ha (of this, moving earth cost \$10,725 per ha)	MB 74% cheaper
Steam, Brazil	\$ 29.00 per ha for materials 0.8% of production costs	\$ 45.60 per ha for materials, 1.3% of production costs	MB 36% cheaper
Steam, Colombia	\$ 4,932 per ha	\$ 18,519 per ha	MB 73% cheaper, but growers prefer performance of steam
Sheet steaming, hired boiler, UK	n/a	\$ 2,642 -5,087 per 2000 m²	Some types steam similar cost to MB
Sheet steaming, purchased boiler, UK	n/a	\$ 5,531 - 7,014 per 2000 m²	MB cheaper
Hood steaming, hired boiler, UK	n/a	\$ 1,950 per 2000 m²	Steam similar cost to MB
Hood steaming, purchased boiler, UK	n/a	\$ 5,498 per 2000 m²	MB cheaper
Negative pressure, Netherlands	Cost:\$ 1.66 per m² Profit:\$6.00 per m²	Cost:\$1.43 -1.74 per m² Profit:\$6.03 per m²	Some steam 14% cheaper, some slightly more expensive, Steam gives 0.5% higher profit average

7.4. Examples of Costs of Substrate Systems

7.4.1. Seed Trays for Tobacco Seedbeds in Zimbabwe

The cost of tobacco seedlings grown with MB in Zimbabwe is estimated to be about US$131-137 per hectare, assuming Trichoderma is not used (ZTA 1995). Seedlings grown in soil substitutes (eg. pine bark) in seed trays by a commercial nursery cost about US$240 per hectare of adult plants (see Table 7.6). The cost of seed trays, however, needs to be adjusted to take account of the fact that farmers would no longer need seedbeds and could use the land for additional crop production. The cost of transporting seed trays will vary according to the distance between the farm and nursery, and is likely to be cost-effective only for farms that are reasonably close to nurseries. Seedlings would cost less if trays were prepared by commercial nurseries and then germinated by farmers themselves. The actual seedlings would cost about 50% less, although some on-farm labour would also be required. Adoption of such a system would require development of local industries to provide quantities of seed trays and suitable soil substitutes.

Table 7.6

Cost of using MB compared to seed trays for tobacco in Zimbabwe.

Inputs	MB costs (US$/ha) by nursery	Seed trays germinated by farmer	Seed trays germinated
MB and other pesticides	97	0	0
Tent and other inputs	used	0	0
Labour	used	0	used
Production of seedlings in seedtrays	0	239	102
Transport	0	variable	variable
Total	**>131**	**>239**	**>102**

Source: Wilkinson 1995.

7.4.2. Substrates for Tobacco Seedlings in Brazil

A UNDP study calculated that the material cost of soil-less substrates for tobacco seedlings in Brazil was US$85.56 per hectare (2.4% of total production costs). This compares with material cost of US$29.00 for MB (0.8% of total production costs) (UNDP 1995). The study pointed out that although soil-less substrates are more than twice the cost of MB they are well received by users because of their simplicity and reliability (UNDP 1995).

7.4.3. Seed Trays for Paprika Seedbeds in Zimbabwe

An assessment conducted for this project estimated the cost of a system using MB for paprika seedbeds in Zimbabwe to be US$368 per hectare, compared to US$977 for seed trays purchased from commercial nurseries (Hedges 1995) (see Table 7.7). Using MB costs 62% less than using this seed tray system for paprika. An increased yield of almost half a tonne would be required from the seed tray system to offset the increased cost, but it is unlikely that this level of yield increase would be achieved. The case study on direct sowing of paprika seeds in Section 7.5 illustrates a much cheaper option.

7.4.4. Peat Substrates for Strawberries in Netherlands

Using a substrate (peat) for glasshouse strawberries in the Netherlands costs US$2.79 per m² for the first ten years and about US$1.86 thereafter. This compares with US$0.65 - 1.27 for a system using MB. However, yields from the substrate system are more than double the yields from using MB, so substrates give greater profits of US$27.58/m², compared to $11.44/m² for MB (De Barro 1995).

TABLE 7.7

Cost of using MB compared to seed trays for paprika spice in Zimbabwe.

Inputs	MB costs (US$/ha of adult plants)	Seed tray costs (US$/ha of adult plants)
MB chemical	36.69	0
Seeds & seedbeds	103.70	0
Commercial nursery production and transport	0	679.49
Transplanting	37.85	55.64
Other pesticides	51.47	51.47
Labour	88.87	58.92
Miscellaneous costs (including interest)	49.58	131.61
Total variable costs	**368.13**	**977.13**
Cost per established seedling	**0.82**	**2.17**

Note: Calculated on basis that 1 hectare of adult plants requires 120 m² seedbed area.
Source: Hedges, Hy-Veld Seed Co, Harare, 1995.

7.4.5. Rockwool Substrates for Cucurbits in the Netherlands

Substrate (rockwool) systems for cucumber production in the Netherlands have an operating cost of US$21.62 per m², and give three crops per year. This compares with an operating cost of US$8.02 per m² using MB, and giving a single crop per year. The profit (revenue minus operating expenses) from the triple-crop substrate system is US$26 per m², compared to US$6 per m² using MB (De Barro 1995).

7.4.6. Summary of Examples of Substrate Costs

There is a great variety of substrate materials and system costs. For the cases where we were able to find comparisons of substrates and MB costs, substrates (including seed trays) were cheaper in two out of six cases. At one end of the spectrum MB was 77% cheaper than the alternative, and at the other end of the spectrum substrates were 10% cheaper than using MB.

In the two cases where data on profits were available, substrates were more profitable (by 141% and 333%) than using MB.

7.5. Example of Costs of Direct Sowing

7.5.1. Direct Sowing of Paprika Seeds in Zimbabwe

If paprika seeds are planted directly into the field rather than sown in seedbeds, improved irrigation and planting techniques are required. Direct sowing is used on approximately 50 hectares in Zimbabwe, and paprika companies expect that the area will increase markedly in

TABLE 7.8
Summary of examples of substrates and seed tray system costs.

Example of alternative	Cost of MB (US$)	Cost of alternative example (US$)	Cost comparison
Commercial seed trays, tobacco, Zimbabwe	\$131 - 137 per ha	\$239 per ha	MB 44% cheaper
Seed trays cultivated by farmer, Zimbabwe	\$131 - 137 per ha	\$102 per ha excluding transport	Seed trays 23% cheaper (excl. transport)
Substrates, tobacco, Brazil	\$29 per ha for materials, 0.8% of production costs	\$86 per ha for materials, 2.4% of production costs	MB 66% cheaper
Commercial seed trays, paprika, Zimbabwe	\$368 per ha	\$977 per ha	MB 62% cheaper
Substrates (peat), strawberries, Netherlands	Cost: \$0.65 - 1.27 per m^2 Profit: \$11.44 per m^2	Cost: \$2.79 per m^2 Profit: \$27.58 per m^2	MB 54-77% cheaper, but substrates give profit 141% higher
Substrates (rockwool), cucurbits, Netherlands	Cost: \$8.02 per m^2 for 1 crop p.a. Profit: \$6 per m^2 for 3 crops p.a.	Cost: \$21.62 per m^2 Profit: \$26 per m^2	Substrate 10% cheaper, substrate gives profit .333% higher
Direct sowing, paprika, Zimbabwe	\$368 per ha	\$486 per ha, but gives other advantages	MB 24% cheaper, but equivalent overall cost/benefit

the next few years. Hy-Veld Seed Co. is actively advocating this method because of its inherent advantages in terms of yield and reduction in MB use (Hedges 1995). A study carried out for this project estimated that use of MB for seedbeds costs US\$368 compared to US\$486 for direct sowing. Using MB costs 24% less than direct sowing (see Table 7.9). However, direct sowing has several advantages, such as reduction in mechanically transferred diseases, closer plant spacing, better root systems, increased yields (under good management) and earlier harvesting. As a result, direct sowing is economically viable compared to using MB (Hedges 1995).

TABLE 7.9
Cost of using MB compared to direct sowing for paprika spice seeds in Zimbabwe.

Inputs	MB costs (US\$/ha of adult plants)	Direct sowing costs(US\$/ha of adult plants)
MB chemical	36.69	0
Seeds and seedbed inputs	103.70	0
Seeds and extra land preparation	0	315.51
Planting & production	37.85	46.78
Other pesticides	51.47	35.07
Labour	88.87	8.00
Miscellaneous (incl. interest)	49.58	65.43
Total variable costs	**368.13**	**485.75**
Cost per established seedling	**0.82**	**1.08**

Source: Hedges, Hy-Veld Seed Co, Harare, Zimbabwe.

Photographer: T.R. Hedges, HyVeld Seed Co.

Paprika crop in Zimbabwe, grown with methyl bromide, shown 20 weeks after sowing date. Plants are grown initially in fumigated seedbeds, then planted out.

Photographer: T.R. Hedges, HyVeld Seed Co.

Paprika crop in Zimbabwe, grown without use of methyl bromide, shown 16 weeks after sowing date. Seeds are planted directly into the field, producing a superior rooting system, and healthier plants that mature six weeks earlier than crops grown with methyl bromide.

7.6. Examples of Costs of IPM and Mixed Techniques

7.6.1. IPM Systems in General

Well-designed IPM systems entail a mix of pest monitoring, cultivation practices and minimal use of target-specific chemicals, and are often cheaper to operate and/or more profitable than conventional chemical methods once the system is established. Some examples include:

- IPM is used for tomatoes, snow peas and broccoli in Guatemala. For tomatoes, net revenues using IPM are US$1,526 per hectare, compared to US$1,156 using conventional methods. For broccoli, net revenues using IPM are US$936 per hectare, compared to US$828 for conventional methods. Net revenues are also higher when IPM is used for snow peas (see Table 7.10) (USAID et al 1994 in Thrupp 1995).

- IPM used for cabbage in Malaysia gave marketable yields 5-6% higher than conventional methods and increased profits up to six-fold (Loke et al 1990).

- An IPM system used for tomato production in Mexico was found to give net profits ranging from US$304 to US$579 per hectare higher than production using conventional pesticide inputs (Trumble & Alvarado-Rodriguez 1993).

Table 7.10

Costs of vegetable production using conventional and IPM methods in Guatemala.

Crop grown in Guatemala	Conventional cultivation using pesticides (US$/ha)	IPM methods (US$/ha)
Tomatoes	Costs: 2,536 Profit: 1,156	Costs: 2,166 Profit: 1,526
Broccoli	Costs: 1,332 Profit: 828	Costs: 1,224 Profit: 936
Snow peas	Costs: 2,879 Profit: 3,583	Costs: 2,634 Profit: 3,828

Source: USAID et al. 1994 in Thrupp 1995.

- An IPM programme introduced in a horticultural region that relied heavily on insecticides and fungicides in Ontario led to a 25-40% reduction in pesticide use and net savings of about US$100 per hectare. IPM was widely accepted by the growers and grower organisations (Surgeoner & Roberts 1993).

- A large-scale IPM training programme for vegetable production in Sri Lanka increased yields significantly. The profits from IPM chilli production are 100,300 rupee/hectare, compared to 30,800 rupee/hectare using conventional pesticides. For cabbage, IPM profits are 150,500 rupee/hectare, compared to 20,000 rupee/hectare using conventional pesticides (Jones 1996).

- A detailed evaluation of IPM has been made by the FAO in Asia, where IPM has been adopted on a large scale for rice production (FAO 1994). Over 570,000 farmers have been trained in IPM in seven countries. The study found that IPM training improved crop yields and substantially reduced expenditure on pesticides in each country. In India, for example, about 50,000 rice farmers were trained to use IPM. Their pesticide costs were reduced to US$9 per hectare on average compared to US$25 per hectare for farmers who have not been trained. IPM yields were 5.5 tonnes per hectare on average compared to 5.1 tonnes for conventional chemical methods (FAO 1994). In the Philippines, for example, 175,000 farmers have been trained in IPM. The IPM farmers had average pesticide costs of about US$13 per hectare compared to US$26, while average yields were 5.1 tonnes/hectare compared to 5.0 (FAO 1994). The FAO noted that IPM offers a way to increase farmers' profits while protecting human health and the environment (FAO 1991b:25).

7.6.2. IPM/Composting for Cut Flowers in Colombia

A system of IPM and sophisticated composting is used for flower production in Colombia, which has one of the most successful cut flower export industries in the world. It provides an example of a very widely used and well-established alternative. The entire alternative production system costs about US$4,930 per hectare compared to US$6,827 per hectare for a production system based on using MB (Rodriguez-Kabana & Martinez-Ochoa 1995). MB is 39% more expensive than the alternative.

7.6.3. IPM/Solarisation for Tomatoes in Sicily

Solarisation in the Ragusa region of Sicily costs approximately US$1,260 per hectare, compared to approximately US$3,780 for MB. It has been calculated that tomatoes grown in Ragusa using a combination of solarisation and IPM would give profits approximately US$2,000 per hectare higher than using MB (Vickers 1995).

7.6.4. IPM/Solarisation in Italy

An IPM/solarisation system is used for a variety of crops in a very intensive horticultural area beside Lake Bracciano in the Lazio region of Italy. According to MBTOC, the cost of this alternative is very low compared to using either MB or steam (MBTOC 1994:100). The cost of solarisation was about US$550-600 per hectare, although this is now likely to be higher. MB is no longer permitted in the area beside Lake Bracciano, so cost data are not available. However, as an approximate indicator, MB fumigation in another part of Italy costs US$3,700 per hectare (MBTOC 1994:100). The IPM/solarisation technique has received a favorable reaction from farmers, on economic as well as other grounds, and has been so successful that it will be applied to other parts of the region (MBTOC 1994).

7.6.5. IPM/Pesticides for Strawberries in the Netherlands

The profitability of open-field strawberries grown using IPM and pesticides has increased since MB was phased out in the Netherlands (De Barro 1995).

7.6.6. Summary of Examples of IPM System Costs

Diversity among IPM systems is even greater than among the other alternatives. For the cases where we were able to find comparisons of IPM and MB costs, IPM systems were cheaper (by 28% to 67%). In each case the alternatives were also more profitable.

Table 7.1
Summary of examples of IPM system costs.

Example of alternative	Cost of MB (US$)	Cost of alternative example (US$)	Cost comparison
IPM/composting, flowers, Colombia	$6,827 per ha	$4,930 per ha	IPM/composting 28% cheaper, and more profitable
IPM/solarisation, tomatoes, Italy	Cost: $3,780 per ha	Cost: $1,260 per ha Profit: c. $2,000 per ha higher than using MB	IPM/solarisation 67% cheaper, and gives profits $2,000/ha higher than MB
IPM/solarisation, various crops, Italy	Cost: approx. $3,700 per ha	Cost: >$600 per ha.	IPM/solarisation much cheaper, and more profitable

7.7. Examples of Costs of Chemical Treatments for Soil

7.7.1. Tagetes Extract Nematicide for Flowers in Kenya

Methyl Bromide, sometimes with additional nematicides, is used by rose producers to reduce the risk of Root Knot nematodes. A study in Kenya has calculated that the labour and chemical cost for this method is approximately US$1,200 per month per hectare of rose plants. Trials with a local plant extract (Tagetes minuta) were reported to cost US$200 per month for an equally effective treatment (Okioga 1994). Some trials with Tagetes have been carried out in Zimbabwe and are continuing.

Table 7.12
Cost of using MB compared to dazomet for pepper seedbeds in Chile.

Inputs	MB cost (US$/ha)	Dazomet cost (US$/ha)
Soil preparation	236	236
Chemical product	160	2,170
Tractor with driver	75	75
Machine application	105	105
Plastic (0.1mm)	2,625	2,625
Sowing by machine	250	250
Irrigation labour	0	50
Labour	150	312
Total	**3,601**	**5,823**

Source: Francisco J Rojas, ETEC, Santiago, 1995.

7.7.2. Dazomet for pepper seedbeds in Chile

Dazomet is not a complete replacement for MB. In Chile, it is reported to give a germination rate of 70-80% compared to 90% for MB, while the crop output using dazomet is lower. A cost assessment carried out for this project estimated that use of MB in

Chile costs about US$3,600 per hectare, compared to about US$5,820 for dazomet, suggesting that MB is 38% cheaper than this alternative (Rojas 1995) (see Table 7.12).

7.7.3. Dazomet for Processed Tomato Seedbeds in Chile

In Chile, germination of tomatoes using dazomet varies from 60 to 85%, whereas germination using MB reaches 85%. The output and control of pests, insects and weeds is reported to be similar. However, the longer waiting time for dazomet, combined with adverse weather conditions can lead in effect to an increased cost of 250% for processed tomato producers in Chile (Rojas 1995).

Cost calculations made for this study estimate that use of MB on processed tomato seedbeds in Chile costs about US$3,640 per hectare. Treatment with dazomet is estimated to cost about US$6,210, suggesting an additional cost of 70% (Rojas 1995) (see Table 7.13).

Table 7.13

Cost of using MB compared to dazomet for tomato seedbeds in Chile.

Resources required	MB cost (US$/ha)	Dazomet cost (US$/ha)
Land preparation	236	236
Chemical product	200	2,604
Tractor with driver	75	75
Machine application	105	105
Plastic (0.1mm)	2,625	2,625
Sowing by machine	250	250
Labour	150	312
Total	**3,641**	**6,207**

Source: Francisco J Rojas, ETEC, Santiago, 1995.

7.7.4. Metam sodium and Manure for Strawberries in South Africa

The cost of using a combination of metam sodium, manure and several cultivation techniques (eg. plastic mulch for weed control) for strawberries in South Africa amounts to about US$4,054 per hectare. Using the 'hot gas' method of applying MB costs about US$3,908, so the alternative is about 4% more expensive (Cassidy 1995) (see Table 7.14). If MB is currently used only once every two years the alternative would be relatively more expensive. However, the cold gas method of applying MB costs about 21% more than the alternative.

Many of the techniques used in this alternative system would be effective for strawberries and runnerbeans in Zimbabwe (Cassidy 1995).

Table 7.14

Costs of using MB compared to metam-sodium and other techniques for strawberries in South Africa.

Inputs	MB - cold gas method (US$/ha)	MB - hot gas method (US$/ha)	MB - every two years (US$/ha)	Metam sodium cost (US$/ha)
MB	2,169	1,180	493	0
Metam sodium and chlorpyrifos	0	0	0	850
Other pesticides	2,728	2,728	> 2,728	2,728
Manure	0	0	0	476
Total	**4,897**	**3,908**	**> 3,221**	**4,054**

Source: Cassidy 1995.

7.7.5. Metam-sodium for Cut Flowers in Colombia

An entire production system for cut flowers based on metam sodium in Colombia would cost US$7,583 per hectare per year, compared to US$6,827 for MB (Rodriguez-Kabana & Martinez-Ochoa 1995:14). In this case MB would be 10% cheaper.

7.7.6. Dazomet and EDB for Strawberries in Zimbabwe

Use of a combination of dazomet, EDB, chlorpyrifos and other pesticides for strawberry production in Zimbabwe is estimated to cost more than US$5,480 per hectare compared to more than US$4,460 for a combination of MB and other pesticides (see Table 7.15). Using MB is about 19% cheaper than the other system. While the chemical product EDB is a cheap nematicide compared to MB, it is listed by the IARC as a suspected carcinogen, posing an occupational safety hazard that is likely to result in undesirable externalised costs (WHO 1992).

Table 7.15

Cost of using MB compared to EDB/dazomet for strawberries in Zimbabwe.

Inputs	MB system cost (US$/ha)	Dazomet/ EDB system cost (US$/ha)
Pesticides for plants (eg. benomyl)	595	595
Dazomet for nursery	0	4,186
Field pesticides (MB, or EDB and chlorpyrifos)	3,299	136
Other weekly pesticide inputs (eg. carbaryl, dichlofluanid, clofentezine)	498	498
Tent hire	34	34
Applicator	yes	7
Protective clothing	yes	28
Labour	yes	yes
Total	**4,460**	**>5,483**

Source: Wilkinson 1995.

7.7.7. EDB for Runnerbeans in Zimbabwe

Use of EDB (at 60 litre/hectare) for controlling nematodes for runnerbeans in Zimbabwe was found to cost about US$766 compared to US$2,320 for a professional application of MB (Wilkinson 1995) (see Table 7.16). In this case using MB costs 203% more than EDB, however, EDB poses occupational safety problems (WHO 1992).

Table 7.16

Cost of using MB compared to EDB for runnerbeans in Zimbabwe.

Inputs	MB cost (US$/ha)	EDB cost (US$/ha)
MB applied by pest control company	2,045	0
EDB	0	276
Other chemicals	275	490
Total	**2,320**	**>766**

Source: Wilkinson 1995.

7.7.8. Summary of Examples of Chemical Alternative Costs

As with other alternatives, chemical systems and costs are very diverse. For the cases comparing costs with MB, alternative chemical systems were cheaper in one case (by 67%). In the five other cases, MB varied from 4% cheaper to 41% cheaper.

TABLE 7.17
Summary of examples of costs of chemical alternatives for soil.

Example of alternative treatment	Cost of MB (US$ per ha)	Cost of example of alternative (US$ per ha)	Cost comparison
Dazomet, pepper - Chile	$3,601	$5,823	MB 38% cheaper
Dazomet, tomato - Chile	$3,641	$6,207	MB 41% cheaper
Dazomet & EDB, strawberries - Zimbabwe	>$4,460	>$5,483	MB 19% cheaper
EDB, runnerbeans - Zimbabwe	$2,320	>$766	EDB 67% cheaper
Metam-sodium and manure, strawberries - South Africa	$3,908	$4,054	MB 4% cheaper
Metam-sodium, flowers - Colombia	$6,827	$7,583	MB 10% cheaper

7.8. Examples of Costs of Alternatives for Stored Products

7.8.1. PHOSPHINE FOR GRAIN IN ZIMBABWE

The GMB has estimated that (at local prices) the cost of purchasing phosphine chemical is about three times the cost of MB. For 1.8 million tonnes of stacked grains the additional chemical cost would amount to US$500,000 according to GMB calculations (GMB 1993).

Another study has also examined the cost of sheeting. The cost of purchasing the MB chemical for grain fumigation in Zimbabwe has been estimated to be approximately US$221,520 for 2.5 million tonnes of grain; the cost of phosphine chemical to treat the same amount of grain has been estimated to be about US$355,843 (Taylor 1995). Phosphine treatment is slower, so additional fumigation sheets would also be required. Assuming that 3,500 additional sheets might be needed and that each sheet costs US$2,326, then the cost of additional sheets for phosphine treatments might be approximately US$8,141,000 (Taylor 1995).

It may be possible to reduce these figures by using less expensive brands of phosphine. Recent changes in the role of GMB make it unlikely that such large quantities of grain will be stored in the future. Nevertheless, the additional cost of phosphine and sheeting provides a substantial barrier to its use in Zimbabwe.

7.8.2. PHOSPHINE AND CARBON DIOXIDE FOR GRAIN IN THE PHILIPPINES

Studies in the Philippines have compared the costs of treatments for stored grains (milled rice). MB is no longer used for stored grain in the Philippines, however it would cost about US$1,900 to treat stacks of 300 tonnes of bagged grain in storage for 6 months. Using a conventional method of applying phosphine costs about US$2,152 for the same period (see Table 7.18). Improved techniques of applying phosphine (for example, using a floorsheet) have been found to lower the cost. It could also be lowered by using a cheaper brand of phosphine.

Phosphine used in a sealed enclosure containing 300 tonnes of grain (milled rice) and stored for 16 months was found to cost about US$1,380. Using carbon dioxide for the same period cost about US$1,965. However, carbon dioxide maintains the quality of the grain noticeably better than MB or phosphine (Sidik 1995).

Carbon dioxide gas in the Philippines tends to be expensive compared to some other countries in the region, so there is scope for reducing costs by utilising a cheap source of CO_2 such as by-products from the cracking process of oil refineries. After the initial investment has been made, the running costs of both alternatives can often be cheaper than MB for grain in long-term storage.

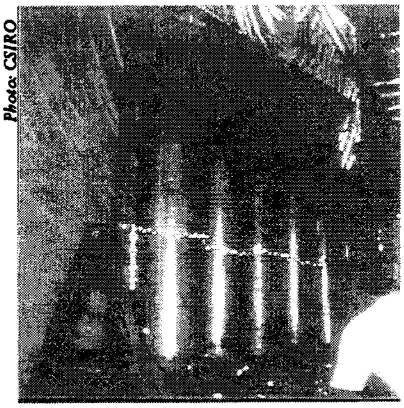


Photo: CSIRO

Carbon dioxide applied from cylinders to a stack of stored rice which has been sealed and tested for gas tightness.

TABLE 7.18

Cost of using MB compared to phosphine and carbon dioxide for stored grain (milled rice) in the Philippines.

Storage costs for 300 tonnes of bagged grain	MB - 6 month storage (US$)	Conventional phosphine - 6 month storage (US$)	Phosphine in sealed enclosure - 16 months (US$)	Carbon dioxide in sealed enclosure - 16 months (US$)
Variable direct costs	221	552	184	778
Fixed direct costs	1,532	1,082	1,021	1,145
Losses due to insects	150	518	173	42
Total	**1,903**	**2,152**	**1,378**	**1,965**

Source: NAPHIRE 1995.

TABLE 7.19

Cost of using MB compared to phosphine and carbon dioxide for stored grain (maize) in the Philippines.

Storage costs for 250 tonnes of bagged grain	Conventional phosphine - 5 month storage (US$)	Phosphine in sealed enclosure - 5 months (US$)	Carbon dioxide in sealed enclosure - 5 months (US$)
Variable direct costs	472	179	673
Fixed direct costs	1,082	1,021	1,146
Losses due to insects	2,617	597	447
Total	**4,171**	**1,797**	**2,266**

Source: CSIRO 1992.

7.8.3. Carbon Dioxide and Phosphine for Grain Storage in Malaysia

The cost of two treatments for bag-stack grains (milled rice) have been compared in Malaysia. For four months of storage, phosphine was found to be cheaper than carbon dioxide, costing US$2.24 per tonne of grain compared to US$2.52. But, from the sixth month, carbon dioxide becomes the cheaper storage treatment. At one year, phosphine costs US$3.49 per tonne of grain, compared to US$2.52 for carbon dioxide (CSIRO 1992) (see Table 7.20).

Table 7.20
Costs of using carbon dioxide and phosphine for stored grain (milled rice) in Malaysia.

Cost as time progresses	Phosphine treatment (US$/tonne grain)	Carbon dioxide treatment (US$/tonne)
Initial fixed cost per tonne of grain	1.28	2.52
Total cost at 4 months	2.24	2.52
Total cost at 6 months	2.53	2.52
Total cost at 8 months	3.06	2.52
Total cost at one year	3.49	2.52

Source: CSIRO 1992.

7.8.4. Phosphine, Carbon Dioxide and Vacuum Systems in Indonesia

For a six-month period, phosphine costs US$0.61 - 0.79 per tonne of grain, compared to US$0.50 for MB in Indonesia. Calculations are based on a conversion rate of approximately 2,000 Indonesian Rupiah (Rp) to US$1. For six-month storage, the carbon dioxide system was more expensive, at US$2.43 per tonne (see Table 7.21). However, significantly cheaper carbon dioxide techniques can now be used, and were demonstrated by CSIRO staff in Zimbabwe in 1995.

When grain is stored for 12 months in Indonesia, the cost of carbon dioxide (using a relatively expensive carbon dioxide system) remains higher than MB or phosphine (see Table 7.22). Analyses of direct costs of different methods found that after 12 -14 months, carbon dioxide is the cheapest method (Suharno 1986, Conway et al 1989). An analysis of both costs and rice losses determined that carbon dioxide becomes as cheap as phosphine after about 9 months storage (Nataredja & Hodges 1989).

Carbon dioxide is generally more effective than phosphine in controlling insect pests and mold growth. Rice stored under carbon dioxide also tends to maintain quality better (particularly odour and appearance) so it often fetches higher prices than rice treated by conventional fumigants. For example, rice stored in Jakarta for 2.5 years using carbon dioxide was sold at 225-230 Rp/kg, almost 8% higher than rice treated with conventional fumigants (210-215 Rp/kg) (Nataredja & Hodges 1989).

The vacuum container system is substantially more expensive than the other systems, at US$44 per tonne.

Table 7.21
Cost of using MB, phosphine, carbon dioxide and vacuum container system for grain stored for six months in Indonesia.

Cost for six month period	MB (US$/ tonne)	Phosphine (US$/ tonne)	Carbon dioxide (US$/ tonne)	Vacuum (US$/ tonne)
Equipment	0.43	0.56 - 0.74	2.43	35.00 [1]
Operating cost	0.07	0.05	0.003	15.00
Direct costs	0.50	0.61 - 0.79	2.43	50.00

[1] Excluding capital cost of plant construction.
Source: Compiled from data in Sidik 1995.

TABLE 7.22

Cost of using MB, phosphine and carbon dioxide for grain stored for twelve months in Indonesia. Costs exclude grain losses.

Cost for 12 month period	MB (US$/ tonne)	Phosphine (US$/ tonne)	Carbon dioxide (US$/ tonne)
Equipment	0.62	0.96 - 1.33	2.43
Operating cost	0.14	0.10	0.005
Direct costs	0.76	1.06 - 1.42	2.44

Source: Compiled from data in Sidik 1995.

7.9. Conclusions on Costs

A number of case studies have compared the costs of using MB with the use of alternatives. Some alternatives cost substantially more than using MB, whereas certain techniques of solarisation, steam, substrates, IPM and chemical treatments have been found to have lower costs and/or higher profits than using MB.

Each term such as 'steam treatment', 'IPM', 'solarisation' or 'phosphine fumigation' covers a wide range of techniques, so each should be regarded as a family of techniques rather than a single one. The members of each family have very different cost implications. We found examples where alternatives carrying the same name were in fact very different techniques, some of which had similar costs to MB and others of which had much higher costs. In most cases where the techniques are expensive, there are also cheaper techniques in the same family. Therefore, if alternatives are selected carefully it would be possible to introduce alternatives with comparable or lower operating costs than MB. Conversely, alternatives can be unnecessarily expensive if careful selection is not made.

It would be useful to MB users and future project funders if UNEP or another UN agency would consider establishing a database which identifies and describes for each family of alternatives the techniques which are most cost-effective.

We also found that the costs in countries where alternatives are well-established or widely used were often lower than in countries where they are rarely used. This is due to factors such as cost-savings from efficiencies of scale and commercial pressures having produced improvements in techniques over time. This indicates that the costs of alternatives introduced into new areas are likely to become lower over time, as a result of normal market pressures.

To put these comparative costs into context, it is important to note that the cost of pest control in a number of cases is a small fraction of the total cost of producing and marketing vegetables, fruit and cut flowers. Some of the examples from Brazil clearly showed that the cost of any treatment such as MB, substrates, steam or solarisation was less than 2.5% of the total production cost (UNDP 1995). Likewise, data on tobacco costs in Zimbabwe show that use of MB represents a small proportion of the total costs; seedbed costs represent about 4.5% of the average cost of producing, curing, transporting and selling one hectare of tobacco (ZTA 1995).

Like MB, some alternatives, especially some alternative chemicals, pose safety hazards (costs) to operators and the environment and in some cases to the general community. These externalised costs are not normally included in cost comparisons, with the result that MB and some alternatives (eg. EDB) appear cheaper than they really are (see Section 7.13 on externalised costs).

7.10. Resources Required for MB Replacement

In the majority of cases, some form of information and/or training is necessary at a minimum, in order for alternatives to be adopted by users. Certain alternatives would also require some capital investment at user level, or investment in supply industries at regional level. Since a number of alternatives have lower operating costs than MB, there is potential for growers to get a good return on investment if alternatives are carefully selected. IPM, for example, normally requires a higher level of information and skill than other alternatives and the conversion cost can present a substantial barrier; but if this is overcome the operating costs can become substantially lower and give growers better profits. The large-scale IPM training programmes carried out by the FAO provide an illustration of the economic benefits, and the practical feasibility of large numbers of farmers converting to IPM methods (Section 7.6.1).

Standard partial budgeting techniques are applicable to the problem of identifying the costs of replacing MB with alternative treatments at farm or enterprise levels (Rae 1995), and are summarised in Appendix 1.

There are several major areas where resources will be required in order to replace MB, which are outlined below.

7.10.1. Expertise and Research Facilities

Additional research will be needed in a number of cases to apply alternatives to the specific pests, crops and conditions of the region. This is especially true for IPM systems. Research would also be beneficial to improve the efficacy or costs of certain alternatives, especially of alternatives that are better for the environment. This will require resources such as researchers with specialist knowledge and experience of the development of alternatives, the facilities of agricultural research institutes in developing countries, and the input of growers participating in on-farm research. Experts and agricultural research institutes in a number of developing countries have already started to examine alternatives.

Research will not be required in all cases. Some soil alternatives can be directly transferred from one site to another (eg. modern steam systems, some substrate systems and some fumigants). Successful IPM systems can often be transferred to more farms where the same pests arise in the local region (and sometimes further afield). For stored products, alternative fumigants can often be introduced without the need for additional research. For other alternatives, further work would often be required to apply them to new areas. Research will be especially important in the area of quarantine, where further research, development and demonstration trials will be necessary in a number of cases.

7.10.2. Establishment of New Service and Manufacturing Industries

There is need for resources to build up or create service and manufacturing industries to provide a wide range of services and equipment related to alternatives, such as IPM advisory services, cheap sources of CO_2 by-product gas, processing of waste materials to make substrates, large-scale manufacture of seed trays and other agricultural equipment and products.

7.10.3. Conversion Costs at Farm/Enterprise Level

There is need for financial assistance for purchasing capital equipment and one-off expenditure associated with conversion to alternatives, such as new equipment, specialist advice, and training. There will also be a need for assistance to meet on-going additional operating costs where they arise, for example, labour, chemical or biological products. However, if alternatives are carefully selected, additional operating costs could be avoided in many cases.

7.10.4. Training and Technical Advice

Alternatives for soil and stored products do not normally require sophisticated equipment, except in a few cases. The transfer of skills and knowledge will be considerably more important than transfer of technology (equipment or other hardware). In some countries large numbers of growers will need training in techniques such as IPM, as well as sources of independent information and advice. Training of agricultural consultants and farm advisers will be important because they have a crucial role in determining the techniques used by farmers. However, many currently recommend MB because they are not sufficiently familiar with alternative techniques. Large-scale training programmes in IPM have demonstrated the feasibility and effectiveness of training large numbers of farmers in developing countries (FAO 1994, Jones 1996).

7.11. *Examples of Required Resources*

7.11.1. Resources for Tobacco Seedbeds in Zimbabwe

Zimbabwe's Tobacco Research Board (TRB) is actively examining potential alternatives to MB, including IPM and seed tray systems. The TRB has good technical facilities. For example, it receives a larger number of technical journals than any other research institute in Zimbabwe, including the University of Zimbabwe. TRB researchers also interact with other scientists by attending foreign conferences and visiting other institutions.

To avoid dependency on one pest control method in the future, it is desirable to develop several alternative techniques, such as fixed concrete seedbeds, substrates, steam and seed tray systems. The following types of resources would be required:

- Further research and development work at TRB. The recruitment of researchers with long-standing experience in specific alternative systems, to assist experts at the TRB.

- Loans or grants for commercial companies to manufacture necessary equipment. To establish, for example, industries making seed trays, producing soil substitutes from local waste materials, providing concrete or blocks for permanent seedbeds, pipes and fans for steam systems, or expanding production of biological controls. Eventually, loans would also be needed, for example, for nurseries to purchase additional trays, seed planting equipment, and other items to increase output.

- Growers would need resources for items such as training, setting up permanent seedbeds or steam pipe systems, any additional labour or costs related to alternatives, or additional transport costs due to use of seed trays.

7.11.2. Resources for IPM for Cut Flowers

The development and use of IPM for cut flowers would require resources for:

- Regionally coordinated research to determine the most effective and cost-effective mix of IPM techniques. In a number of cases existing IPM systems could be adapted to suit new regions; the amount of necessary research would vary according to the pest spectrum and other conditions. The process would be speeded up if researchers with considerable experience in using IPM systems for cut flowers could be recruited to work with growers and research institutes in the regions needing alternatives. Flower industry specialists from Colombia, for example, offer considerable skills in this area.

- loans or grants to help local industry to establish or expand production of necessary items, such as pest monitoring equipment, biological controls, equipment for cultivation practices, processing of waste materials to produce substrates or soil amendments, etc.;
- training programmes for growers, agricultural advisers and consultants; and
- resources for growers to make the conversion, such as pest monitoring equipment, establishment of new systems and procedures, and costs of any additional labour, chemicals, biological controls or other equipment.

7.11.3. Resources for Carbon Dioxide Treatment for Stored Grain

In order to introduce carbon dioxide as an alternative for stored grain, the following resources would be needed:

- equipment to capture (and where necessary scrub) and distribute cheap sources of carbon dioxide, such as by-products from distilleries or cracking processes at oil refineries;
- loans or grants to establish or expand local industries to produce appropriate glues and fumigation sheets; and
- financial assistance to users for training and equipment such as fixed enclosures, airtight sheeting, special glues, and gas monitoring equipment.

7.11.4. Resources for Phosphine for Export Grains

Using phosphine takes at least 5 days (at 30°C) compared to about 2 days for MB. Fumigations with either MB or phosphine must be carried out under monitored and well-sealed conditions for adequate duration. In the case of phosphine this is particularly necessary to prevent further increases in pest resistance. The longer time to fumigate a given depot increases the risk of cross-infestation, so more fumigations are likely to be necessary. Extra demurrage charges will also be incurred. Using phosphine would require the following capital and running costs:

- users would require training, monitoring equipment, additional sheeting material, and any additional costs for the phosphine chemical, exporting companies may need training in procedures and planning to manage fumigations over a longer timescale;
- in countries where the cost of phosphine is relatively high, resources are needed to investigate cheaper brands or sources of the chemical; and
- additional demurrage charges due to longer treatment time.

7.11.5. Resources for Quarantine Treatments

For cut flowers, for example, pre-shipment inspection and certification is a common alternative to MB because MB can cause significant damage to flowers (MBTOC 1994:221). However, pre-shipment inspection is not effective for certain pests and flowers, and quarantine authorities of importing countries require fumigation with MB prior to export. In such cases research is needed to develop techniques based on changes in field procedures as well as post-harvest treatments:

- research to develop effective pre-harvest procedures, and post-harvest techniques to kill specific pests in specific commodities;
- compilation of dossiers to demonstrate that the techniques provide full quarantine security;
- resources for experts familiar with importing country quarantine procedures to assist with negotiations to gain approval for the technique; and
- resources for capital equipment and training, and for any additional operating costs associated with using the treatments.

The cost of negotiations could be substantial if the importing countries are not prepared to accept demonstrated alternatives to MB. In such cases the prime barrier would be the policy of the importing countries.

7.12. *Sources of Financial Assistance*

The availability of financial assistance will be essential for reducing reliance on MB in developing countries. The Multilateral Fund is able to finance projects on MB now that Article 5 countries have agreed to some controls. The replenishment of the Fund, and additional resources for the replacement of MB, will be necessary for assisting progress. However, increasing demands on the Fund and political pressures within industrialised countries to limit expenditure on the Fund, are leading the Parties to examine more diverse sources of funding. There are several other possible sources of financial assistance for action on MB. Examples include:

- **Re-orienting Existing Agricultural and IPM Programmes**
  Governments of industrialised countries, international agencies such as the FAO, agricultural institutes, NGOs and the World Bank currently operate diverse agricultural programmes in developing countries, assisting in training, technology transfer and research. Programmes relating to horticulture and stored products could be reviewed to see whether some can be re-focused to assist the adoption of environmentally sound alternatives to MB. The FAO, for example, could consider extending successful IPM training programmes to horticultural sectors using MB.

  As a first step, organisations could examine current policies and projects to ensure that they do not actively promote use of MB. The World Bank has undertaken a preliminary survey of its projects in the Agricultural and Natural Resource Division (Formo 1995). Any Bank-financed project likely to include use of MB or other pesticide is likely to require a full Environmental Analysis (Category A) (under Bank procedures OD 4.01, Annex

E). A Bank Memo notes that the promotion of IPM alternatives in research and project implementation would be consistent with the Bank's efforts to improve pest management practices (under GP 4.03, Part II, Para 7) (Formo 1995).

- **Programmes under Agenda 21 of the Earth Summit**
  The United Nations Conference on Environmental Development (UNCED) Earth Summit agreement on sustainable agriculture and rural development (Chapter 14 of Agenda 21) included specific objectives for governments to promote IPM and non-chemical pest control methods (UNCED 1992) (see Chapter 8 for a list of commitments in the agreement). Funding mechanisms are still under discussion by the Commission on Sustainable Development. There are opportunities to integrate work on the IPM objectives of Chapter 14 of Agenda 21 (such as building up regional IPM networks) with the replacement of MB by IPM and non-chemical methods in certain sectors, to provide more cost-efficient use of funds.

- **National Agricultural Subsidies and Loans**
  Governments in some developing nations currently provide financial assistance for agricultural development, in the form of agricultural payments or subsidies or favourable loans. Any payments or loans to sectors using MB could be reviewed with a view to altering incentives to encourage growers to adopt environmentally sound alternatives. Changing the criteria for receiving existing agricultural support payments, to make payments dependent upon meeting certain environmental criteria, has been identified as an important policy instrument for reducing the environmental impacts of agriculture (Baldock et al 1993).

- **Re-orienting Existing Development and Export Programmes**
  Some rural development and industrial development programmes could be re-focused to help create infrastructure, management programmes, training schemes, grants, loans, or other assistance to establish or expand companies and local industries supplying alternatives in developing countries. Programmes which provide loans or funds for export industries could also assist developing countries to establish new export industries to help meet the future demand for alternatives to MB.

- **Import Licence Fees**
  In the vast majority of cases the MB used in developing countries is imported. Governments in importing countries could consider setting up a licence fee for MB imports. Beginning in 1996, Australia will charge an import licence handling fee of A$90 per tonne of imported MB, and importers will have to purchase licences at a cost of A$10,000 for two years (Australian EPA 1995). Such a scheme should ideally be fiscally neutral so that the majority of the revenue could be used to assist the replacement of MB.

- **Voluntary Levy**
  Some large companies using MB in developing countries, such as certain flower producing companies in Africa, are owned by multinational companies which are well-resourced. Such companies could consider placing a voluntary levy on their own use of MB, to assist other users to adopt replacements. Fruit and vegetable growers in a region of Australia have set up a voluntary levy of 20 cents per kilogram MB, collected at wholesale level by the importer, starting 1 September 1995. The levy is expected to raise A$150,000 per

year for the development of alternatives in the region (Nufarm 1995). If a levy were adopted by multinational companies using MB in developing countries, revenue could be passed to the national Ozone Unit to assist smaller users to adopt environmentally sound alternatives.

7.13. Externalised Costs of Methyl Bromide Use

Use of MB itself entails a number of costs. Methyl bromide is a relatively expensive pesticide, which has to be imported into most of the countries that use it. Zimbabwe, for example, paid at least US$1,200,000 for imports of MB in 1994. In addition to the cost of purchasing the chemical, there are also externalised costs such as ozone layer depletion and residues in soil, crops and sometimes water. Externalised costs are carried by the environment rather than being included in the price the grower pays for fumigation or that the final consumer pays for a food product. As a result, food produced using MB appears cheaper than it really is, passing hidden costs on to others. The main externalised cost of using MB, as with other ozone depleting substances, will arise from raised levels of UV-B radiation, which will increase medical costs and impose costs on agriculture, forestry, fisheries and tourist industries (see Chapter 2).

Other externalised costs arise because MB normally leaves residues of bromide ion and a range of other poorly defined residues and metabolites. Bromide ion residues are of relatively low toxicity and raise toxicological concerns only if above certain levels. There is limited information about the other residues and metabolites. Nevertheless, the addition of residues to the environment (soil, crops, local air and sometimes water) contributes to the general problem of environmental contamination and is not good agricultural practice. Table 7.23 summarises the environmental impacts of using MB. Emissions reduction techniques would help to reduce emissions to the air and atmosphere but will generally lead to higher levels of residues in soil, crops and/or water.

7.13.1. Residues in Soil

MB breaks down into a variety of residues, often leaving raised levels of inorganic bromide and other residues in soil.

- Inorganic bromide residues in fumigated soil have been reported to range from a few milligrams up to 218 mg/kg (ACP 1992). Raised levels of bromide in the soil have been reported to persist in some cases for four years (Fallico & Ferrante 1991).
- Inorganic bromide occurs naturally in the soil at low levels, and is bound tightly to the soil. In contrast, the bromide from MB fumigation is initially free to move and be taken up by plants or washed out by water (WHO 1995).
- Carnations can be damaged by inorganic bromide in the soil if precautions are not taken (Kempton & Maw 1974). Certain crops such as pepper, celery and onion do not reach adequate growth when grown in fumigated soil (Bromine & Chemicals Ltd 1990), unless residues are reduced by leaching soil with copious amounts of water or planting is delayed. Dead Sea Bromine recommends that MB fumigation should not be used for celery nursery crops (Klein 1996).

7.13.2. Impacts on Soil Microflora and Nitrogen

A well-conducted fumigation destroys injurious pests but also destroys a variety of beneficial and non-target organisms, such as earthworms and some soil microflora, altering the trophic structure of the soil environment (Van Rhee 1977, WHO 1995, Sassaman et al 1986). This can have negative consequences. Some examples include:

- The elimination of many soil organisms is a disadvantage if unwanted pests enter a fumigated field on new plants or from deeper soil or neighbouring land - they may multiply rapidly in the absence of many competing species or predators (Conway & Pretty 1991). The Florida Department of Agriculture reports that MB fumigations can sometimes lead to disease because pathogens are able to become much more active in soil free from many competing micro-organisms.

- Repeated MB fumigations may sometimes lead to reductions in plant growth, due to activity of pathogens such as *Pythium* (Vickers 1995). Repeated fumigations can destroy naturally occurring saprophytic *Fusaria,* beneficial micro-organisms which suppress the development of fusarium wilt.

- 'Successful' MB fumigations can sometimes create mycorrhizal deficiencies, which lead to costly crop failures (Barnard 1995). Dead Sea Bromine notes that if decreased crop growth occurs after fumigation the most common cause is the effect of MB on beneficial microflora, especially mycorrhizae which are extremely susceptible to MB (Klein 1996, Menge 1982, Menge et al 1979).

- Soil studies show that MB fumigations (especially repeated fumigations) reduce several key enzymatic activities of soil microorganisms. Reduced microbial activity reduces the capacity of soil to retain nitrogen, allowing it to be leached more easily (Rodriguez-Kabana 1996).

7.13.3. Water Residues

After fumigation, soil is sometimes leached with large quantities of water to reduce residues. Dead Sea Bromine notes that soil leaching after MB fumigation is needed for two reasons: (1) to eliminate toxic residues which cause phytotoxicity to sensitive crops and (2) to prevent accumulation of bromides in the edible parts of vegetables, especially in leafy crops (Klein 1996). Deliberate leaching, heavy rain and irrigation systems can in some cases transport residues into surface or groundwater.

- The IPCS/WHO has noted that relatively high levels of inorganic bromide (up to 72 mg/litre) can be found in drainage water from greenhouses and could adversely affect aquatic organisms. The long-term No Observed Effect Level (NOEL) toxicity indicator value for different fish species is 25 mg bromide/litre (IPCS 1994).

- Concentrations of MB per se have occasionally been found, at levels of up to 9.3 mg/litre in drainage water (IPCS 1994). IPCS reports the EC50 or LC50 toxicity indicator values to be 0.3 mg/litre for fish and 1.7 mg/litre for daphnids.

7.13.4. Food Residues

Plant species differ in their ability to take up bromide and other residues. Accumulation of bromide ion is greater in leaves than in crop roots or fruit such as tomatoes (Klein 1996). Leafy

TABLE 7.23
Local and global environmental impacts resulting from use of MB.

Occurrence of residues	Examples of impacts
Global impacts	
Stratosphere	• Humans: increased risk of non-melanoma skin cancers, cataracts, immune suppression • Certain crops: disrupted growth, less disease resistance, reduced yields • Grazing animals: increased incidence of disease • Forests: disrupted growth and reduced yields in certain species • Fisheries: reduced fish stocks • Certain building materials: reduced useful life
Local impacts	
Soil	• Some beneficial organisms destroyed eg. earthworms, micro-organisms that inhibit crop diseases • Phytotoxicity in certain crops eg. carnations - requiring ameliorative action such as leaching
Water	
- *unintended run-off* - *deliberate leaching*	• Groundwater: contamination in some situations • Water organisms: potential hazard to fish and water organisms as a result of leaching in certain areas
Food	
- soil treatment residues - post-harvest treatments	• Leafy vegetables: raised bromide ion levels and other residues or metabolites • Oily foods eg. oily nuts: MB residues sometimes occur after post-harvest treatment • Milk: potential residues if MB is used intensively on low-lying land
Air in vicinity of fumigation sites	
	• Agricultural workers: occupational hazard from skin exposure or inhalation • Local community: potential exposure • Birds, mammals and pets: potential exposure

vegetables, such as lettuce and celery, have been found with high bromide levels, so MB manufacturers recommend that soil should be leached with water or that the interval between fumigation and planting is as long as possible (Klein 1996).

- Comparing residues in crops grown on fumigated and non-fumigated soil, a study found bromide residues in tomatoes were about two times higher in the crop grown on fumigated soil, and remained higher for four successive harvests after a single MB fumigation (Fallico & Ferrante 1991).

- Bromide residues are generally considered to be acceptable if they are below the legal limits, or Maximum Residue Levels (MRLs), but in some cases crop residues are found to exceed the MRLs.

- When MB is applied as a post-harvest treatment to commodities that contain oil or fat, such as walnuts, residues of MB per se can remain in the food. This is undesirable since MB is a potentially toxic compound (ACP 1992; WHO 1995).

7.13.5. Air Contamination

Methyl bromide is classified as highly toxic to people, with a TLV (an exposure threshold) of 0.065 mg/l air (Royal Society of Chemistry 1994). MB is recognized by the WHO and other official bodies to be a toxic substance, which can pose risks to operator safety (IPCS 1994). Cases of operator poisonings in the past led many governments to introduce controls on use for soil and post-harvest commodities. Methyl bromide may now be applied only by licensed operators in most industrialised countries. Legal limits for occupational exposure vary from 1 mg/m^3 in the Netherlands to 20 mg/m^3 in the UK and 60 mg/m^3 in Italy (IPCS 1994; van Haasteren 1995).

Methyl bromide concentrations in soil and between soil and sheeting during commercial fumigations can vary from 250 to 10,000 mg hr/l, even within the same glasshouse (ACP 1992). As with other poisonous gases, excessive exposures or accidents can occasionally occur, even where there are regulatory controls. Some examples include:

- In California MB can legally be used only by licensed operators. Nevertheless, there were 148 recorded cases of systemic illness, 52 eye injuries and 60 cases of skin injury due to MB between 1982 and 1990 (Brodberg et al 1992).

- MB levels up to 1 mg/m^3 have been found up to 20 m from a greenhouse four days after it was fumigated. Air concentrations up to 900 ppb have been measured in adjacent fields 100 m away from fumigated fields (Brodberg et al 1992).

7.14. Economic Benefits from Replacing Methyl Bromide

In addition to reducing the costs resulting from ozone depletion in the future, and other externalised costs, the replacement of MB would provide developing countries with opportunities for direct economic benefits.

7.14.1. Improved Yields and Profitability

The examples of operating costs, yields and profitability given above show that selected alternatives would allow growers to increase yields and profits. A well-designed IPM system, for example, often gives higher profits than conventional pesticide methods, as illustrated by experience in Colombia, Mexico, Guatemala, Sri Lanka and a number of other countries. Soil substitutes, particularly cheaper, natural substrates, offer opportunities for significantly increasing productivity and profitability.

7.14.2. Competitive, Modern Approaches to Horticulture

The cut flower export industry in Colombia, which has almost totally abandoned the use of MB, illustrates that fact that industries using alternatives can be very competitive. Colombia is one of the largest flower exporters in the world, in a highly competitive international market. Colombia competes with countries in Latin America and Africa (such as Kenya, which relies heavily on MB). Colombian producers have been obliged in the last decade to increase cost-efficiency and to diversify into new flower varieties. They more than doubled the volume and value of flower exports between 1985 and 1993, despite abandoning use of MB (Rodriguez-Kabana & Martinez-Ochoa 1995). The industry says that continuing improvements in agronomic knowledge and active on-farm research are essential to its success in the competitive world market. In contrast to some other flower exporting nations, yields (per hectare) in Colombia are increasing (Rodriguez-Kabana & Martinez-Ochoa 1995).

A detailed case study on alternatives to MB in the Netherlands concluded that the widespread adoption of alternatives as a result of phasing-out MB made it very much easier for other productive methods to be adopted by the horticultural industry. The removal of MB acted as a catalyst for the widespread development of new and improved agricultural production techniques and systems. Development has continued, giving further improvements in performance and environmental impact (De Barro 1995).

Many broad spectrum pesticides are no longer used in agriculture and are regarded as outmoded methods of pest control, because they destroy both damaging and beneficial organisms. Replacing MB provides an opportunity for developing countries to modernise horticultural approaches and help ensure future competitiveness of these sectors.

7.14.3. Generating Employment

Horticulture normally uses more labour than other types of agriculture. Table 7.24 gives examples of labour requirements for weed control, comparing MB and other treatments. These labour measurements apply to USA application techniques and practices, and some hours would differ in other countries. For example, MB application is often automated in the USA: tractors inject soil with the fumigant and may automatically lay sheeting as they move over the field. In Zimbabwe and Chile sheeting is normally done manually, and a small canister of gas punctured under the sheeting. Nevertheless, the data illustrate the general point that different techniques often require substantially different labour inputs. If alternatives are carefully selected, it would be possible to create employment when MB is replaced. This is an important aspect because unemployment in rural areas is often a substantial and growing problem.

Low-chemical IPM systems, for example, generally replace chemical inputs with labour and skill. Table 7.25 compares agrochemical inputs and labour inputs on about 200 conventional and about 90 low-chemical IPM farms over a two-year period. The conventional farms spent more on agrochemical inputs while the IPM farms spent more on labour. The additional labour costs can be offset by reduced expenditure on agrochemical inputs (Table 7.25). On average 23% of the total cost (per hectare) on conventional farms was for pesticides and other agrochemicals, compared to 7% on IPM farms. Labour comprised 2% of the total cost (per hectare) on conventional farms while it comprised 8% of the cost on low-chemical IPM farms.

Table 7.24
Examples of labour requirements for weed control, comparing MB and some alternatives (USA data).

Weed control treatment	Labour required for 0.1 acre for 6 months
MB	11 hours
Solarisation with metam sodium fumigant	14 hours
Chloropicrin	16 hours
Metam sodium	16 hours
Solarisation	22 hours
No treatment, hand weeding	33 hours

Source: Larson & Shaw 1994

A detailed study found that conventional farms use on average 6 units of labour (per 100 hectares) compared to 10 on low-chemical IPM farms (see Table 7.26). Another study compared labour on 36 low-chemical IPM farms and 36 conventional farms, calculating that IPM farms used 5.5 labour units per hectare compared to 2.8 labour units per hectare on average (Rude 1990, Dubgaard et al 1990). Although using different units, both studies indicate that low-chemical IPM farms can require almost double the labour. This applies to small holdings in particular. The data in Table 7.26 came from farms in Europe; the differences in developing countries may be more marked.

TABLE 7.25

Comparison of costs of labour and agro-chemical inputs on about 200 conventional farms and about 90 low-chemical IPM farms, over a 2 year period (1988-90).

Type of inputs	Cost on conventional farms (cost/ hectare)	Cost on IPM farms (cost/ Hectare)
Pesticides and other agro-chemical products	US$1,636	US$426
Labour	157	511
Total	**7,017**	**6,568**

Source: Lampkin 1992.

TABLE 7.26

Use of labour on small and large farms, comparing conventional farms with low-chemical IPM farms.

Farm size	Labour on conventional farms (labour units per 100 hectares)	Labour on IPM farms (labour units per 100 hectares)
Under 10 hectares	23	60
10-20 hectares	10	14
Over 50 hectares	3	5
Average	**6**	**10**

Source: Lampkin 1992.

7.14.4. Increasing Skill Levels

Some of the alternatives to MB, especially IPM techniques, require higher skill levels. More skilled agricultural workers would benefit developing economies, allowing more scope for flexibility and diversification.

7.14.5. Developing New Industries

The replacement of MB in Zimbabwe, Thailand and Chile would require the expansion of some existing industries and the development of a variety of new industries to provide products, pest control services and training at domestic level. These countries are also in a position to develop new export products and services to help meet regional and international demands for alternatives. Examples of opportunities for new industries include:

- processing and recycling waste products (eg. forestry industry waste) to use as soil substitutes or soil amendments;
- recycling plastic waste to produce seed trays;
- manufacturing biological controls and pesticidal plant extracts (Zimbabwe already produces commercial biological control agents and has the opportunity to expand production);
- manufacturing plastic sheets for solarisation;

- manufacturing additional fumigation sheets for phosphine treatments;
- manufacturing specialised sheets and glues for carbon dioxide treatments;
- capturing, and where necessary scrubbing, carbon dioxide by-products from distilleries, oil refinery cracking processes, smelters; and
- making equipment for heat treatments, hot water dips, and cold treatments for quarantine.

Examples of new or expanded service industries include:

- providing portable steam boilers and steam treatments;
- providing soil pest monitoring and identification services;
- providing research services to further develop or apply alternatives;
- providing consultancy and information services to advise growers and MB users on alternative methods of pest control; and
- training programmes on the use of alternatives.

7.14.6. Prioritising Local Economies

It would benefit the economies of Zimbabwe, Thailand and Chile if alternatives were based as much as possible on local resources, local industries and local employment, rather than on imported equipment and chemicals. MB is an expensive pesticide and Zimbabwe alone paid at least US$1,200,000 in foreign exchange earnings for imports of the chemical product in 1994. Replacing MB provides opportunities for import substitution, allowing much of current expenditure on MB to remain within the economies of developing countries rather than being transferred to chemical companies in the USA or Israel.

7.14.7. Environmental Improvements

Certain alternatives have much lower impact on the environment than MB. By selecting these, developing countries have an opportunity to reduce externalised costs.

7.14.8. Diversification and Production for Niche Markets

Some alternatives provide opportunities for diversification in horticultural exports. Techniques that give greater control over planting time, for example, allow crops to be sold at times when they can gain higher prices. In some cases more skilled production would assist growers to keep pace with consumer fashions in horticultural products, such as specialist vegetables or flowers. There are other opportunities to increase production for niche markets. Uganda, for example, has developed a trade in organic exports to Europe which is growing at the rate of 20% per annum (Mavondo 1995), and countries such as Zimbabwe have the potential to convert some horticultural production in a similar manner.

7.14.9. Technology Transfer between Developing Nations

A number of alternatives to MB have been developed and are successfully used in developing countries. There are many opportunities for transferring experience, expertise and technology between developing countries, helping the economies of both partners.

7.14.10. Reducing Dependency

Many sectors using MB have become heavily dependent on this one technique. It would be desirable to develop several alternative techniques for each sector (rather than one alternative), to prevent vulnerability from heavy dependence on one technique in the future. Several alternatives would also help to meet the capacity demand, and suit the needs of different users and situations. There would also be benefits in reducing dependency on MB if restricted supplies in future lead to price rises; or if emission reduction technologies are introduced, raising the cost of using MB.

7.15. Commercial Issues

7.15.1. Market Pressures

Commercial pressures to move away from MB are likely to increase as the public and media become fully aware of the link between MB and ozone depletion. Some companies exporting products grown or treated with MB are already experiencing market pressures to use alternatives. Examples of commercial trends follow.

- In Zimbabwe, for example, tobacco exporters have been told by some European importers that they will no longer accept MB as a pre-shipment treatment; phosphine is used instead. Some companies purchasing tobacco from Asia also no longer accept MB treatments (UNDP 1995).
- A large retail chain in the UK (Sainsbury's) aims by the end of 1996 to purchase the majority of its local and imported fruit and vegetables from producers who use IPM systems. Other major retail chains in northern Europe and North America are also actively encouraging suppliers to reduce pesticides and utilise IPM (non-chemical methods and target-specific pesticides).
- In response to a survey, three large UK retail chains (Sainsbury's, Asda) endorsed EU phase out of MB by the year 2000, or sooner where alternatives exist. A large international fresh produce trader, Geest, said it supported EU phase out by 2000 provided economic alternatives were found (SAFE 1994).

Currently there is not widespread public awareness of the environmental problems associated with MB. Public awareness is likely to grow as ozone depletion increases over the next few years (see Chapter 2). In response to market pressures, retail chains and traders may, where feasible, select produce from suppliers who do not use MB. There is already substantial competition in international trade in fresh produce, and importers and large retail chains are able to switch from one supplier to another. Countries that depend heavily on MB may suffer uncertainty and a loss of exports as a result of market pressures. Conversely, countries that adopt alternatives early may gain a comparative advantage over competitors.

7.15.2. Consumer Demands for Labeling

In the USA, products manufactured with CFCs and traded between states are normally labeled with a warning statement about ozone depletion, as a requirement of the Clean Air Act. Some consumer and environmental organisations have been pressing the EPA to introduce labeling for products grown with MB so that consumers can exercise a choice in what they purchase (NRDC 1994). Consumer organisations for many years have pointed out that consumers have a right to more information about the manner in which food products are produced and that markets cannot operate efficiently unless consumers are provided with sufficient information to distinguish between products (IOCU 1991).

In Monterey, a US region using large amounts of MB, a publicity campaign started in August 1995 to encourage consumers to purchase strawberries grown without MB (Kreider 1995). If there is strong consumer demand, some retailers may respond by encouraging declarations on labels, to inform consumers that MB has or has not been used.

7.15.3. Commercial Disruption

The 1994 UNEP Scientific Assessment of Ozone Layer Depletion confirmed that MB is a significant problem for the ozone layer. The Assessment calculated that eliminating human emissions of MB would have an impact on the extent of ozone loss (WMO 1994:10.23). As ozone depletion increases in the next few years, public pressure to phase out remaining ozone depleting substances is likely to increase, with pressure for all countries to agree to phase out MB. Countries that start early in drawing up plans for MB replacement, and encourage industry to move towards alternatives will have more time in which to make a transition; and change will occur in a more orderly and planned manner, reducing disruption to industry. Where countries do not encourage early planning, industry is likely to face greater disruption in the long term.

7.16. Cost Benefit Overview

There is no standard method for conducting a cost benefit analysis to compare use of MB with the costs and benefits of a potential phase-out in developing countries.

Studies in certain industrialised countries have attempted to examine the overall costs of phase out. They have often used standard partial equilibrium analysis techniques, measuring economic losses in terms of changes in consumer surplus and producer surplus. Examples include USA studies by US Department of Agriculture's National Agricultural Pesticide Impact Assessment Program (USDA/NAPIAP) and Dudley & Maddox in 1993, and a Japanese study by the Association of MB Industry of Japan in 1993. These studies were given a preliminary evaluation by the chair of UNEP's Economic Options Committee. The USDA/NAPIAP study, for example, was found to be limited because it assumed an immediate ban, estimated effects for year 1 only, and ignored a number of alternatives. These assumptions generated much higher estimates of economic cost than one might reasonably expect (Van Slooten 1994:2-3). Likewise, the US study by Dudley and Maddox was criticised because the analysis seriously over-stated the social costs and under-stated the benefits of the control options (Van Slooten 1994:5). An economic study on the situation in Japan was found to have similar shortcomings.

In southern Europe, preliminary cost benefit analysis (CBA) studies have looked at the economic implications of phasing out MB fumigation in Italy, Spain and France (Perez 1994, Bonte 1994, Schimmenti & di Franco 1994). These studies contribute some useful data but due to lack of time they have focused on a small part of the spectrum of costs and benefits, and do not provide a complete picture (Prospect 1995).

The majority of studies to date have tended to look at only one side of the equation - the costs. One of the exceptions is a US EPA review which attempted to quantify benefits as well as costs (EPA 1993). It estimated that costs of a phase-out from 1994 to 2010 to be US$1.7 to $2.3 billion; benefits were estimated at $14 to $56 billion (EPA 1993).

A quantitative cost-benefit analysis has not been conducted for this study, however, a number of qualitative factors have been identified, and these provide an overview of the costs and benefits of replacing and retaining MB. Examples of the costs and the benefits associated are listed below.

Examples of Costs Associated with Replacing MB:

- introducing alternatives: research, development and/or change-over and training costs;
- reduced yields and changes in crop production if alternatives with good yields are not prioritised or if insufficient resources are put into training, independent information etc.;
- reduced markets if insufficient support means that alternatives are poorly selected and product prices rise compared to competitors; and
- public and environmental costs (occupational safety, water and food residues) if least-toxic alternatives are not selected.

Examples of Costs Arising from Use of MB:

- loss of trade in countries where consumer pressure encourages supermarkets and traders to avoid purchasing produce produced with MB - due to ozone concerns and trend for lower residues;
- future medical costs from increases in immune suppression, non-melanoma skin cancer, and possibly cataracts, that many result from increased UV in the future;
- costs and disruption to agriculture, forestry and fisheries from disruption, disease and reduced production in certain crops, outdoor livestock and fish stocks - due to increased UV radiation in future;
- future costs and disruption to tourist industries in sunny climates, due to tourists' efforts to reduce personal UV exposure;
- public and environmental costs (increases in food residues due to emission reduction technology, occupational safety, water residues in some regions); and
- costs of research, development, training and introduction of emission reduction technologies and recapture/recycling equipment.

Examples of Economic Opportunities from Use of MB:

- manufacturing plant to make less permeable sheeting and equipment for reducing emissions or recapture/recycling.

Examples of Economic Opportunities from Replacing MB:

- improved horticultural yields in areas suitable for simple soil substitutes;

- mid- to long-term cost savings and increased profitability for farmers, if alternatives with lower operating costs are used, such as IPM and cheap soil substitutes;
- increased employment in rural areas, if alternatives which generate employment are prioritised (eg. IPM);
- opportunities for industrial and agricultural innovation and development of a range of new local industries to sell pest control products and services; and
- reducing externalised costs in the areas of occupational safety, water and crop residues, if least-toxic alternatives are prioritised.

CHAPTER 8

Replacing Methyl Bromide:

Options and Constraints

THIS CHAPTER EXAMINES DIVERSE FACTORS THAT PROMOTE OR IMPEDE THE ADOPTION OF ALTERNATIVES TO METHYL BROMIDE (MB). IT PROVIDES A DISCUSSION OF THE FEASIBILITY OF THE PHASE-OUT SCENARIOS EXAMINED BY TEAP. THE BENEFITS AND DRAWBACKS OF A GRACE PERIOD ARE ALSO OUTLINED.

8.1. Factors Affecting the Rate of Phase-Out

UNEP has published a report examining the factors that promote and impede phase-out of ozone depleting substances (ODS) in developing countries. The report is called The Review Under Paragraph 8 of Article 5 (UNEP 1994a). A number of representatives of developing (Article 5) countries were interviewed for this report. The factors cited as impediments to phase out ODS included the following (UNEP 1994a:ES-6):

- lack of awareness about phase-out among companies in developing countries;
- lack of information about alternative techniques;
- lack of a national Ozone Protection Unit, or recent establishment of a unit.
- lack of funding or capital for conversion to alternative techniques;
- unavailability of alternative techniques; and
- complicated procedures for receiving Multilateral Fund assistance, particularly regarding funds disbursement.

Factors cited as facilitating phase-out included (UNEP 1994a:ES-6):

- availability of cheaper substitutes;
- foreign ownership of local ODS users, or presence of multinational corporations;
- Multilateral Fund support;

- awareness programmes (both general and targeted); and
- high or rising ODS prices.

The UNEP report also identified the most significant policy and institutional factors determining the rate of phase-out, and divided them into two categories:

1). **Primary factors** -
These directly and unambiguously affect the time it takes to achieve phase-out. Each primary factor can potentially reduce or extend the phase-out time by several years. Examples: market factors and financial support for phase-out.

2). **Secondary factors** -
These affect the phase-out rate by several months to about two years, so have less of an effect. Example: capacity of ODS users to manage change (UNEP 1994a:75-76).

The following sections describe each of the primary and secondary factors, and assesses the likely influence of these factors in affecting the phase-out rate in Zimbabwe and Chile.

8.2. Primary Factors

Tables 8.1 and 8.2 summarise the diverse market factors as they apply to Zimbabwe and Chile. A few market factors are likely to slow down the rate at which these countries can replace and reduce MB. However, in most cases market factors suggest that the two countries will be able to make a more rapid phase-out than a number of other Article 5 countries. The export orientation of MB users and international trade links are especially significant factors. The following section describes each of the market factors and the other primary factors identified by the UNEP study.

8.2.1. Market Factors

8.2.1.1. Industry Structure

The UNEP study found that ODS phase-out actions are fundamentally affected by the export orientation, ownership structure, size and formality of ODS consuming enterprises, and size of existing capital stock requiring constant ODS use (UNEP 1994a:77). These are described below.

Export Orientation

In sectors with a preponderance of export-oriented users, the phase-out of ODS has generally been accelerated (UNEP 1994a:ES-7). The UNEP report noted that exporters have typically moved quickly to protect their export markets. Also, exporting companies often have access to more information about alternatives and new technology, compared to companies without international links (UNEP 1994a:77).

In Zimbabwe about 88% of MB is used by export sectors. The tobacco industry has been active in investigating alternatives, has published information about some recommended alternatives to MB, and has contributed to the MBTOC report. Tobacco leaf traders in Zimbabwe and Asia have been required by some tobacco importers to switch to phosphine (as a pre-shipment treatment). Zimbabwe exporters of strawberries and fresh produce have been active in changing practices - most strawberry producers no longer use MB.

The UNEP report noted that companies tend to be especially active if they export to industrialised countries that have accelerated phase-out requirements (UNEP 1994a:77). A significant proportion of exports from Zimbabwe, for example, go to countries that have set cuts or phase-out dates for MB. The following Zimbabwe sectors and companies may therefore be expected to be especially active:

- tobacco exports to the USA and Europe (some European importers no longer accept MB treatments for tobacco leaves); and
- flower and horticulture producers exporting to the Netherlands, European Union and USA.

Ownership Structure

The UNEP report found that full or part ownership by a government or multinational corporation plays a strong role in driving and facilitating that company's ODS phase-out plans (UNEP 1994a:78). Access to information, technologies, skills and awareness of public image are among the factors affecting multinational corporations. Some MB users in Zimbabwe, for example, are owned by foreign companies.

In at least 3 cases identified by the UNEP study, government control of enterprises helped to accelerate the replacement of ODS (UNEP 1994a:78). Until recently the Grain Marketing Board in Zimbabwe was a para-statal; it uses approximately 13% of national consumption of MB. It has already been active in examining alternatives to MB and reductions in dosage.

Size and Formality of Enterprises

The UNEP study found that phase-out of ODS tends to proceed much more slowly in the small and informal portions of industry sectors (UNEP 1994a:78). Many such sectors are diffuse, lacking in technical sophistication, and not linked to formal institutions, large suppliers or the government. The UNEP report noted that, as a result, diffuse sectors tend to be less informed about phase-out, less likely to initiate phase-out action, more difficult for suppliers, governments and implementing agencies to identify, more difficult to provide information to, and more difficult to organise for MF projects (UNEP 1994a:78).

In Zimbabwe the tobacco sector includes approximately 500 small users - an informal and diffuse group. However, the organisation of the Tobacco Board provides potential for small users to receive information about MB alternatives and funding opportunities.

Existing ODS-dependent Stock

The UNEP report also found that if expensive ODS-using equipment is in place, firms tend to move more slowly to alternatives than do enterprises where the value of the ODS-dependent capital stock is lower.

The value of capital equipment for using MB is relatively low in many cases. The capital equipment for carrying out a soil fumigation, for example, may consist of plastic sheeting, an old steel drum, a spiral copper tube for heating the gas, and a source of heat. The equipment used to fumigate stored grain includes durable sheeting, plastic tubing to distribute the gas, ladders, 'snakes' to hold down the side of the sheeting, and gas detectors. Much of this equipment can be used for phosphine.

Fumigation chambers are normally the most expensive piece of capital equipment associated with MB. However, chambers may often be made suitable for alternative fumigants or converted to controlled atmosphere or heat/cold treatment facilities.

Photo: Natalia Martinez-Ochoa

The introduction of alternatives to methyl bromide offers opportunities for creating new industries in developing countries, to provide alternative products and services. There are also opportunities to utilise waste materials such as rice hulls, seen here for cut flower production in Colombia.

Supply and Cost of ODS and Alternatives

The UNEP study found that the direct cost of ODS versus non-ODS alternatives plays a significant role in helping to drive phase-out in some countries (UNEP 1994a:79). Higher prices for ODS make alternatives more attractive and help encourage research, development and production of new alternatives. However, higher ODS prices may also shift a larger portion of phase-out burden on to local consumers (UNEP 1994a:79).

In the case of MB, the supply to developing countries is currently plentiful. At present MB is being offered at discount prices in some countries; as a result MB use is being extended to new users and new areas. Stock-piling is occurring in some sectors. Prices are not expected to increase until well after the freeze has come into force in 2002. This situation means that MB supply and prices for the foreseeable future will not provide any incentive for users to examine alternatives.

Information Flow

The UNEP report concluded that unless ODS prices to users rise dramatically, significant market interventions are generally required to facilitate factors such as the flow of information about phase-out, price, alternatives and financing. Without reliable information of this type, and with no other incentives, few enterprises can be expected to make potentially costly and disruptive changes in their processes (UNEP 1994a:80).

The UNEP report noted that operation of market forces is affected by the level and quality of information available to producers, suppliers and users. Until these actors receive certain kinds of information, many market forces will not contribute to timely phase-out (UNEP 1994a:80). Important information includes:

- clear, near-term and long-term price signals for ODS and alternatives;
- authoritative data on alternatives (availability, technical and financial details);
- data for alternative producers and suppliers about potential projects in Article 5 countries, to encourage them to market their products and services; and
- information about the availability of financing for phase-out projects (UNEP 1994a:80).

The UNEP study found this information is not flowing openly in many Article 5 countries, and that institutions involved in phase-out efforts are generally not providing a wide distribution of this information at the company level (UNEP 1994a:80). They also found that the majority of companies interviewed lacked complete and reliable information about the impending ODS phase-out and their options for dealing with it. The problem is exacerbated in the small and informal sectors which have fewer links with trade associations or international ties (UNEP 1994a:80). In Zimbabwe and Chile, for example, we found that a number of MB users do not have sufficient quality or quantity of information.

8.2.2. Role of Montreal Protocol and Multilateral Fund

The UNEP report on the Review of Paragraph 8 Under Article 5 identified the importance of the Montreal Protocol, noting that the control schedules affect the supply and market for ODS (UNEP 1994a). In the case of MB it will be a number of years before the freeze agreed by developing countries starts to affect the supply and market.

The report said that funding can be very important. Some Article 5 countries have stated that they will not be able to achieve ODS phase-out by target dates without financial assistance from the Multilateral Fund, (MLF) signifying its symbolic and practical importance (UNEP 1994a:81). Now that controls on MB have been agreed, the MLF is able to fund projects, and guidelines will be developed during 1996.

8.2.3. Role of Article 5 Governments

8.2.3.1. Existence of Ozone Protection Units

The UNEP report noted that governments have an important role in affecting phase-out, by actions such as establishing national Ozone Protection Units (OPU). Without a functioning and responsive OPU the Secretariat and implementing agencies cannot provide services as effectively to the country (UNEP 1994a:81). Zimbabwe's Ministry of Environment and Tourism, for example, has set up an ozone office which is funded by the MLF, and will act as a national information exchange and resource centre. It aims to appraise and assist MLF projects and monitor activities related to ODS (Marongwe 1995).

8.2.3.2. Government Policies

The UNEP study found that Government domestic policies are also important. These may include import quotas, voluntary or mandatory ODS use controls, or taxes on ODS. Such policy actions prompt the flow of information about phase-out and alternatives among companies, and aid more efficient use of ODS. The Zimbabwe government, for example, has indicated its desire to phase out ODS as early as is feasible (Marongwe 1995). The Thai Ministry of Agriculture aims to reduce MB consumption by encouraging use of phosphine for grains where feasible (UNDP 1995).

8.2.4. Time for Societal Transition

The UNEP report noted that the complexity of the phase-out task poses a substantial challenge. The report points out that with limited resources, agencies and individuals must foster difficult technical transformation in diverse economic sectors (UNEP 1994a:82). They must overcome an array of technical, institutional, economic and political constraints. They face many additional constraints, such as critical social policies, limited institutional capacity, sparse technical and economic data, and lack of local experts familiar with alternatives, for example (UNEP 1994a:82). For these reasons alone, rapid phase-out on the same timescale as industrialised countries would normally be extremely difficult or impossible for Article 5 countries.

TABLE 8.1

Primary factors that tend to speed up or slow down the rate of ODS phase-out in Article 5 countries, applied to the situation in Zimbabwe. (These factors were identified by the Review Under Paragraph 8 of Article 5 carried out for the Executive Committee of the Multilateral Fund (UNEP 1994).)

Key: *+ positive effect on phase-out rate* *++ strong positive effect on phase-out rate*
- negative effect on phase-out rate

Primary factors affecting rate of phase out	Situation in Zimbabwe	Likely effect on PO rate
1. *Market dynamics:*		
Export users?	About 88% of MB use is for export	++
Multinational or government ownership?	Some foreign ownership in tobacco and horticulture, grain marketing Board was parastatal until recently	+
Diffuse users?	Not diffuse for grain, tobacco and horticulture diffuse	+ / -
High value MB capital equipment?	Generally low value capital equipment	++
Information on alternatives?	Tobacco Research Board and Grain Marketing Board actively examining alternatives	++
2. *Global commitment & financial support:*		
Montreal Protocol commitment to Phase-Out?	Feeze by 2002, phase-out schedule has not been agreed	+
Assistance from MLF?	Project funds available, but MLF policy not yet established	+
3. *Government policies and OPU?*	Zimbabwe government applied for funds for reducing MB use for grain as part of country programme, OPU due to be established 1995	++

8.3. Secondary Factors Affecting Rate of Phase-out

The UNEP report identified secondary factors that can affect the timing of phase-out by several months to two years. The secondary factors are described below. Tables 8.3 and 8.4 summarise the positive and negative factors relevant to Zimbabwe and Chile. Positive factors predominate in both countries.

8.3.1. Selection of Alternatives at Project Level

UNEP's report found that a number of factors influence how companies identify, evaluate and select replacement technologies or techniques. These factors may include the institutional capacity of the individual company, and the involvement of other actors such as equipment vendors and implementing agencies in the firm's decision making. The report noted that success in this process will result in an efficient enterprise-level ODS phase-out, while failure can lead to delay in phase-out decision making and abandonment of the project. This may occur, for example if technologies do not meet the actual local needs or are not sustainable with local resources (UNEP 1994a:ES-11).

In Zimbabwe, for example, the Tobacco Research Board and Grain Marketing Board will have an essential role in identifying and selecting alternatives.

TABLE 8.2

Primary factors that tend to speed up or slow down the rate of ODS phase-out in Article 5 countries, applied to the situation in Chile.

Key: *+ positive effect on phase-out rate* *++ strong positive effect on phase-out rate*
- negative effect on phase-out rate

Primary factors affecting rate of phase out	Situation in Chile	Likely effect on PO rate
1. *Market dynamics:*		
Export users?	About 85-97% of use is for export	++
Multinational or government ownership?	Some foreign ownership in horticulture and horticulture export	+
Diffuse users?	Companies using post-harvest horticulture treatments are co-ordinated, soil users appear diffuse	+ / -
High value MB capital equipment?	Very low value capital equipment for soil, high value equipment for quarantine (fumigation chambers). - but could be converted for alternatives	++
Information on alternatives?	Agriculture departments, horticulture exporters and government departments actively examining alternatives	++
2. *Global commitment & financial support:*		
Montreal Protocol commitment to Phase-Out?	Freeze by 2002, phase out schedule has not been agreed	+
Assistance from MLF?	Project funds available but MLF policy not yet established	+
3. *Government policies and Ozone Protection Unit?*	Government has encouraged investigation of alternatives and emissions reduction technologies, Ozone Team appointed in 1993 under National Environmental Commission (CONAMA)	++

8.3.2. Terms of Project Financing

Only the incremental costs of ODS phase-out are financed by the MLF. The UNEP report noted that even if incremental costs were fully subsidised, a company may still have little incentive to adopt an alternative technology. Fund grants which do not fully cover all the incremental costs from the company's perspective provide even less incentive for change (UNEP 1994a:ES-11).

In Zimbabwe, Thailand and Chile there are opportunities for funding sector-wide projects, such as tobacco, flowers, tomatoes, pepper, and grain. While the Executive Committee has put in place procedures to allow for sectoral phase-out strategies (including projects with net incremental savings and for concessional loans to help address financing difficulties) there has been little forward movement to develop sector-wide projects to date, according to UNEP's report (UNEP 1994a:ES-11). The Implementing Agencies currently provide only grants, not loans. This is important because the report found that companies in Article 5 countries find it difficult to obtain project financing for ODS phase-out from sources other than the MLF.

TEAP has noted that the specified incremental costs eligible for funding under the MLF and items on the indicative list may need revision in order to accommodate the special needs associated with MB (TEAP 1994:94).

Some alternatives have lower operating costs than MB, but would require initial investment for training and/or equipment. MLF policies on projects with net incremental savings need to be examined in the light of this. IPM, for example, normally increases labour costs slightly to moderately, while reducing the cost of chemical inputs substantially (Chapter 7). The net running cost of low-chemical IPM is likely to be lower than use of MB in many cases. However, IPM requires investment in local application and training, which would act as a barrier for many MB users. It is important that the Fund will be able to help users to overcome such barriers.

8.3.3. Structure and Operation of the Multilateral Fund

The UNEP report noted the perception that differing and confusing priorities and objectives may sometimes emerge between the Executive Committee and the implementing agencies on issues such as cost effectiveness, technical criteria and safety criteria. This may slow technology transfer efforts by requiring repetition of tasks or redesign of projects. The involvement of multiple agencies for administering the MLF also sometimes causes confusion for companies in Article 5 countries, according to UNEP's report (UNEP 1994a).

8.3.4. Structure and Operation of OPUs

UNEP's report found that the capacity and capabilities of OPUs set up by Article 5 country governments have an impact on the rate of phase-out. Some OPUs are autonomous organisations while others are part of larger government agencies, such as the national ministries responsible for environment or finance. Some OPUs have multiple staff dedicated solely to ozone protection issues, while others have staff whose primary responsibilities have little to do with ozone, and other countries do not have anyone working on the issue on a daily basis. Some OPUs are intimately involved in all stages of project development and implementation while others play a passive role (UNEP 1994a:ES-12).

8.4. *Conclusions on Rate of Phase-Out*

The UNEP study concluded that the combination of primary and secondary factors largely determines the rate of phase-out. In some Article 5 countries factors combine to give phase-out almost at the same speed as industrialised countries, while in other countries different factors hinder a rapid phase-out (UNEP 1994a:91).

Tables 8.1 - 8.4 show that Zimbabwe and Chile have a predominance of positive factors, suggesting that they are likely to achieve a more rapid phase-out than a number of other developing countries. The situation of Thailand is similar in key respects. The export orientation of MB users and international trade links are especially important.

Zimbabwe, Thailand and Chile are likely to be cost-efficient areas for funding, in the sense that funding is likely to produce a more rapid reduction in MB than it would in a number of other countries.

TABLE 8.3

Secondary factors affecting the rate of phase out in Article 5 countries, applied to the situation in Zimbabwe. (These lesser factors can affect rate of phase-out by several months to two years (UNEP 1994).)

Key: *+ positive effect on phase-out rate* *++ strong positive effect on phase-out rate*
- negative effect on phase-out rate

Secondary factors affecting phase out rate	Situation in Zimbabwe	Likely effect on PO rate
1. *Process of identifying alternatives at project level*	Tobacco and grain sectors already active in process of identifying potential alternatives, GMB has applied for project funds	++
Current alternatives	Alternatives for some sectors are used in other countries, a few alternatives (eg. phosphine, IPM) are used in Zimbabwe	+
2. *Terms of project financing under MLF*	MLF policy not yet established for MB	-
3. *Operation of MLF*	Not yet applicable to MB	-
4. *Operation of OPU*	Zimbabwe's OPU is due to be fully involved in project appraisal, information exchange etc.	++

TABLE 8.4

Secondary factors affecting the rate of phase-out in Article 5 countries, applied to the situation in Chile.

Key: *+ positive effect on phase-out rate* *++ strong positive effect on phase-out rate*
- negative effect on phase-out rate

Secondary factors affecting phase out rate	Situation in Chile	Likely effect on PO rate
1. *Process of identifying alternatives at project level*	Exporters, export organisations and some growers active in identifying potential alternatives	++
Current alternatives	Alternatives for some sectors are used in other countries, a few alternatives (eg. IPM) are used in Chile	+
2. *Terms of project financing under MLF*	MLF policy not yet established for MB	-
3. *Operation of MLF*	Not yet applicable to MB	-
4. *Operation of OPU*	CONAMA is responsible for managing transfer of investment funds, industry training, awareness	++

8.5. Agricultural Policies to Facilitate Transition

In addition to the factors identified by UNEP's Review, agricultural and rural development policies will also determine the rate of phase-out. By reviewing and adjusting relevant policies, governments and funding bodies would encourage the transfer of technology and know-how, and assist growers and pest control companies to reduce MB consumption. Examples of potential measures:

8.5.1. Adjusting Controls on MB Pesticide Products

Many countries have placed legal controls on the labeling and use of plant protection products such as MB. Controls could be adjusted to encourage the adoption of alternatives, by:

- increasing the interval between MB fumigation treatments; for example, by limiting MB soil treatments to intervals of more than 23 months, 35 months or 47 months, depending on the crop;
- limiting the maximum permitted doses, eg. reducing the permitted dose for a specific crop from 70 g/m^2 to 30 g/m^2, as appropriate; and
- reviewing the list of crops and products for which MB is currently permitted, and where appropriate dropping approval for uses where pests can be controlled successfully by other methods.

8.5.2. Codes of Practice

The adjustments outlined in Section 8.5.1 could initially be encouraged by Codes of Practice, as a matter of good agricultural practice. Some fumigation companies and commercial companies using MB would be able to act more quickly than the authorities, implementing restrictions voluntarily prior to any adjustment to official MB pesticide controls.

8.5.3. Adjusting Agricultural Policy Measures

A number of governments operate agricultural programmes providing subsidies, grants, favourable loans and other forms of assistance to farmers, to promote agricultural development. Such programmes could be reviewed and re-oriented to encourage up-take of environmentally sound alternatives to MB.

8.5.4. Agricultural Research Programmes

It may also be feasible to re-orient some existing agricultural research programmes to adapt and improve existing alternative techniques, using on-farm research in particular, and to develop further methods of pest control in the longer term. Research would benefit from being coordinated at regional level.

8.5.5. Agricultural Extension Programmes

A number of governments operate agricultural extension (education) programmes in conventional and IPM methods. Relevant programmes could be re-oriented to disseminate independent information and advice about alternatives and reduction techniques. Training in environmentally sound techniques would also be an important component, to minimise externalised costs. Extension programmes may also be able to assist in establishing best-practice methods of pest control on leading farms or sites in key regions and sectors, to assist on-site training and demonstrations.

8.5.6. Implementation of Agenda 21

The financial mechanisms for funding the implementation of Agenda 21 are still under discussion. When established, funds will be available to help implement commitments on sustainable agriculture and rural development, such as promoting IPM and non-chemical methods in agriculture. A number of these commitments will also assist in the replacement of MB (see Appendix 2).

8.5.7. Rural Development Programmes

Rural development programmes have become increasingly important in some countries. Some of these programmes could be adjusted to generate employment in horticulture in rural areas by setting up training programmes in low-chemical IPM systems, or providing cheap loans or grants for local companies to provide the necessary services and products for alternatives.

8.6. *Rate of Technology Transfer and Training*

When replacing MB, transfer of technical equipment may be important for a few sectors. However, for most uses the transfer of knowledge and skill will be much more important. Training growers and other users in new skills will be essential. A prerequisite for adapting alternatives will be the availability of appropriate experts to select and refine a suitable mix of practices and treatments. In many cases equipment can be sourced or produced locally. In general the concept of 'skill transfer' or 'technique transfer' is more appropriate than 'technology transfer'.

8.6.1. Cost Effectiveness of Training

The Review of Paragraph 8 Under Article 5 found that training projects had the highest completion rate (56%) among the projects so far approved under the MLF (UNEP 1994a:ES-5). In contrast, about 4% of all investment projects had been completed.

Training projects tend to be of shorter duration and less resource intensive than other projects. Training will be a large component of the cost of replacing MB, particularly for IPM for soil use, but also for post-harvest procedures. This indicates that a significant proportion of funding in the MB area could be spent on projects with a short duration and high completion rate, which would suggest a cost-effective area for funding.

8.6.2. Skill Transfer between Article 5 Countries

The UNEP Review found a few projects were planning transfer of alternatives between Article 5 countries (for ODS other than MB). In the case of MB there will be considerable scope for transfer of skills and techniques between Article 5 countries. For example, the expertise of Colombian IPM experts to flower growers in other regions.

Universities and agricultural research institutes in certain developing countries have specialised in developing IPM techniques, non-chemical controls, and sustainable agriculture practices optimising local resources. These experts will be an invaluable resource in helping to identify and adapt suitable alternatives. IPM training programmes have been developed in a number of Article 5 countries, with the potential for training skills to be transferred.

8.7. *Scenarios for Reductions and Phase-out*

8.7.1. Lessons from Phase-out of CFCs and Halons

TEAP has examined the lessons for MB control from the CFC and halon phase-out. When controls were agreed for CFCs and halons in 1987 few alternatives had been identified (TEAP 1995:21). Users of MB are in a better position because MBTOC has identified technically feasible alternatives for a substantial proportion of MB use at this stage. A number of alternatives to CFCs are now in use, yet in 1987 the industry claimed that:

- no single chemical offered the same advantages;
- if alternatives were possible they would have been identified;
- any substitute would face years of delay from regulatory requirements, testing etc.; and
- competitors in Article 5 countries would gain an unfair advantage by a grace period (TEAP 1995:22).

TEAP noted that in retrospect these early perspectives failed to appreciate the potential for technical innovation, the power of market forces, the efficiency of public/private partnerships, and the leadership of specific companies that pledged early phase-outs. In many cases the alternatives were cost-saving, no cost or low cost. The early pessimism gave way to innovative product development and profitable commercialization (TEAP 1995:22).

TEAP also noted that it is now possible to see that alternatives to CFCs often performed poorly in initial technical evaluations because they were judged against fully optimised CFC technologies. Researchers accepted the conservative business-as-usual estimates of the time necessary to implement technology and/or to secure government approval. For example, routine evaluation of food packaging could take three to five years normally at the US Food & Drug Administration, but was accomplished in less than 60 days at the request of the EPA and with input from a government expert (TEAP 1995:22).

TEAP concluded that more stringent Protocol controls would serve as powerful market incentives to commercialise alternatives, but must also allow adequate time for real (rather than just perceived) barriers to be overcome (TEAP 1995:23).

The reductions and phase-out agreed by industrialised countries, as well as the early phase-outs agreed by the USA and some other countries, will stimulate innovation as with other ODS. TEAP noted that technical innovation has been particularly rapid when:

- Chemical suppliers support ozone layer protection. Unlike DuPont leadership after 1987, MB producers still question the science (TEAP 1995:23).
- Leadership companies set voluntary goals to halt use. So far, few MB customers are publicly demanding rapid change.
- National regulations encourage change. Progress in the Netherlands is an example of such success (TEAP 1995:23).

8.7.2. Potential Control Scenarios Examined by UNEP Panels

The WMO/UNEP Scientific Assessment of 1994 estimated that eliminating agricultural and industrial emissions of MB in the year 2001 would significantly reduce (by 13%) the future calculated levels of chlorine/bromine in the atmosphere (WMO 1994). The MB Technical Options Committee has identified technically feasible alternatives (either currently available or at an advanced stage of development) for a substantial proportion of MB use (MBTOC

1994:3), and this conclusion was recently re-affirmed.

Chapter 6 of this report identified technically feasible alternatives for almost all the non-quarantine and pre-shipment uses of MB in the three case study countries. Chapter 7 found that a number of soil alternatives have operating costs that are similar to or lower than MB, and that the main barrier is the initial investment or transition cost. Some soil alternatives would provide a rapid return on the investment. Alternatives for stored products tend to have higher operating costs than MB, except for long-term storage. However, there is considerable scope for reducing the cost of alternatives for stored products, such as CO_2 systems, by using more efficient methods and cheaper, local materials, as demonstrated by the work of CSIRO. TEAP has noted that provided funding is available, the main barriers to rapid phase-out in developing countries are considered to be largely informational and administrative, rather than technical or economic (TEAP 1994:57). The data in our study have produced the same conclusion.

The Synthesis Report of the Scientific Assessment Panel and Technology and Economic Assessment Panel of March 1995 examined several potential phase out scenarios for Article 5 countries, pointing out the need to take account of the special circumstances of developing countries:

1) **No controls for Article 5 countries -**
In the absence of controls, assuming a 7% annual growth in use, Article 5 country consumption would exceed 90% of the 1991 industrialised country consumption by 2010. This scenario would produce a more than 700% increase in calculated chlorine/bromine levels and associated ozone depletion (TEAP 1995:Syn-6).

2). **Freeze in 1996 at 1996 levels -**
For the most part, alternatives are the same in developing countries as in industrialised countries. Therefore TEAP concluded that it is technically feasible to halt the increase in use in Article 5 countries providing that technology, financing and infrastructure were available. This scenario would increase the calculated chlorine/bromine levels by 0.3-0.4%.

3). **Freeze at 1996 and phase-out by 2011 -**
If industrialised countries phase-out MB by 2001, it is anticipated that a wide variety of alternatives will have been commercialised by that time. In principle, ten years is sufficient time for Article 5 countries to implement these same technologies, providing there is access to new technology, infrastructure development and financing (TEAP 1995:73). There may be some pest situations that are unique to Article 5 countries and may not be solved by the research in industrialised countries. In such cases uses would be approved under an essential use process. This scenario would reduce calculated chlorine/bromine levels by 1.3-1.8%.

4) **Freeze at 1996, 25% cut by 2008, 50% cut by 2011 -**
This scenario is more economically feasible than a complete phase-out. A 50% allowance would accommodate unusual pest situations and difficulties of building infrastructure. This scenario would reduce calculated chlorine/bromine levels by 0.5-0.7% (TEAP 1995:Syn-6).

The scenarios assume an exemption for quarantine and pre-shipment or application of the essential use process.

Estimates of the cost-effectiveness of controlling CFCs and halons may be relevant to MB. A study carried out for the Executive Committee found that where ODS prices rise over time, it is likely that late reductions may result in higher actual costs than earlier reductions. Phase-out of CFCs by the scheduled date (2010) is estimated to cost US$800 million, while phase-out in 2006 would be a cheaper option at about US$470 million (UNEP 1994a:ES-19). Interestingly, phase-out as fast as cost-effectively possible (early reductions, equivalent to phase-out by 2001 with a long servicing tail) was estimated to achieve net savings of US$876 million (UNEP 1994a:ES-19). Given that the full costs of replacing ODS are not provided to Article 5 countries there can be real savings in avoiding late reductions in ODS use.

The UNEP study found that the scenario of phase-out as fast as cost-effectively possible was the best option for cost effectiveness and for ozone layer protection. It indicated that since it will be significantly easier and cheaper to replace ODS in some sectors than others that there could be significant benefits if the Montreal Protocol were to set different phase-out dates for different sectors (uses) (UNEP 1994a:115). In the case of MB this would be technically feasible.

8.8. Role of The Grace Period

Article 5 countries conventionally have an additional ten years for achieving cuts or phase-out in recognition of the additional constraints they face. TEAP's 1995 Assessment discussed the possibilities for shorter grace periods. In the case of halons and CFCs the commercialisation of replacements has occurred much more rapidly than predicted. TEAP noted that in the case of MB there is the need to evaluate whether a grace period of ten years is advisable, in view of the trade implications and possible dumping this would cause (TEAP 1994:58). There is a possibility that markets in industrialised countries will be resistant to products that are produced with the aid of MB and this is an issue of great concern to Article 5 exporters (TEAP 1994:94). Those Article 5 countries with export earnings at risk already have strong market incentives to accelerate phase-outs of export-related MB uses. In view of the potential for trade restrictions and availability of alternatives it may be argued that only a short grace period may be required for MB (TEAP 1994:58).

TEAP also noted that a grace period should be sufficiently long to make the necessary changes to disseminate and support alternatives and to allow continued uninterrupted production of those cash crops and other exports currently dependent on MB (TEAP 1994:58). Industrialised countries may wish to assure that national environmental legislation permits continued importation of produce grown with MB. TEAP concludes that in the end the allowable grace period may be irrelevant if market forces and technical innovation prevail (TEAP 1994:58).

Contacts and Resources

Obtaining Information on Alternatives

THIS CHAPTER PROVIDES A LIST OF CONTACTS AND RESOURCES WHICH CAN PROVIDE INFORMATION ON METHYL BROMIDE, OZONE DEPLETION AND ALTERNATIVES.

International Agencies

Dr. Peter Ooi
Deputy Regional Programme Coordinator
Integrated Pest Control Intercountry Programme
Food & Agriculture Organisation
PO Box 3700 MCPO
1277 Makati
Metro Manila Philippines
tel +632 818 6478
fax +632 812 7725
email: ipm-manila@cgnet.com

- *Information on FAO regional IPM training programmes;*
- *Reports and brochures on IPM methods.*

Dr. Omar E El-Arini
Chief Officer
Multilateral Fund for the Montreal Protocol
27th floor, Montreal Trust Building
1800 McGill College
Avenue Montreal
Quebec H3A 3J6 Canada
tel +1 514 282 1122
fax +1 514 282 0068
email: sysop@mfs.login.qc.ca

- *Information about projects funded by the Multilateral Fund to assist phase-out of ozone depleting substances.*
- *Procedures and guidelines for proposed projects.*

Mr. Frank Pinto
Chief
Montreal Protocol Unit
United Nations Development Programme
1 United Nations Plaza
New York, NY 10017 USA
tel +1 212 906 5042
fax +1 212 906 6947
email: frank.pinto@undp.org

- *Report on UNDP surveys on MB consumption and potential alternatives in English-speaking Africa, South America and South-East Asia and Pacific region (1995);*
- *Information about UNDP projects and programmes.*

Mr. K M Sarma
Coordinator
Ozone Secretariat
United Nations Environment Programme
PO Box 30552
Nairobi, Kenya
tel +254 2 623 885
fax +254 2 521 930
email: madhava.sarma@unep.no

- *MBTOC report on MB alternatives, the '1994 Report of the Methyl Bromide Technical Options Committee';*
- *'Synthesis report on MB: its atmospheric science, technology and economics' (1992);*

- *'Action on ozone' UNEP booklet (1993);*
- *Reports on scientific assessments of the environmental effects of ozone depletion (1991, 1994);*
- *Reports on the Montreal Protocol meetings and decisions.*

Mr. Rajendra Shende
Coordinator
OzonAction Programme
United Nations Environment Programme - Industry & Environment
Tour Mirabeau 39-43
quai Andre Citroen
75739 Paris cedex 15 France
tel +331 4437 1450
fax +331 4437 1474
email: ozonaction@unep.fr

- *UNEP database on alternatives;*
- *Report on regional workshops on MB for English-speaking Africa, South America and South-East Asia and Pacific (1995);*
- *'OzonAction' newsletter;*
- *Information about UNEP OzonAction projects and programmes.*

Mr. A R Ben Brahim
Director, Agro-based Industries Branch
United Nations Industrial Development Organisation
PO Box 300
A-1400 Vienna Austria
tel +431 211 315 542
fax +431 211 316 849

- *Report of UNIDO survey of projects on MB alternatives (due 1996);*
- *Information about UNIDO projects and programmes.*

Mr. Ken Newcombe
World Bank
1818 H Street NW
Washington DC 20433 USA
tel +1 202 477 1234
fax +1 202 522 3256
email: knewcombe@worldbank.org

- *Memo on MB and World Bank agricultural projects from Agricultural and Natural Resource Division (1995);*
- *World Bank policy paper on MB projects (due 1996).*

Dr. Rumen Bojkov
Special Advisor to the Secretary-General
World Meteorological Organisation
41 Avenue Guiseppe-Motta
CH 1211 Geneva 2, Switzerland
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fax +41 22 734 2326
email: ipa@www.wmo.ch

- *Scientific assessments of ozone depletion (1991, 1994);*
- *Scientific information and press releases about ozone depletion.*

Soil (Pre-Plant)

Companies and Research Groups with Expertise in Alternative Methods of Pest Control

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Asian Vegetable Research and Development Centre (AVRDC)
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- *IPM systems for vegetable production; economic analysis.*

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- *IPM systems including soil amendments, biological controls, cultural practices, chemical treatments.*

Mr. Marten Barel
Barel BV
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Veldhoven Netherlands
tel +31 40 253 2726
fax +31 40 253 9565

- *Steam treatments for soil and substrates.*

Ms. Sheila Daar
Bio-Integral Resource Center (BIRC)
PO Box 7414
Berkeley, CA 94707
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tel + 1 510 524 2567
fax + 1 510 524 1758
email: birc@ igc.apc.org
- *'IPM Practitioner' Journal;*
- *Books, reports and leaflets on IPM.*

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Regional Office for Africa
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fax +254 2 747 340
email: cabi-roaf@cabi.org
- *Information about IPM and biological controls; IPM training.*

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- *IPM systems for horticulture.*

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- *IPM systems for vegetables and flowers.*

Dr. Anne Turner
Crop Science Department
University of Zimbabwe
PO Box 167
Harare
Zimbabwe
tel + 263 430 3211
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- *Training in IPM for vegetable crops for small-scale growers.*

Mr. Henk Nuyten
Experimental Garden Breda
Heilaarstraat 230
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tel +31 76 144 382
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- *Substrates for strawberry production.*

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Faculty of Agriculture
The Hebrew University of Jerusalam
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- *Soil solarisation.*

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- *Natural substrates and pest control products.*

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- *IPM consultancy.*

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- *IPM training programmes for horticultural crops; information about IPM systems and methods.*

The Secretary
International Federation of Organic Agriculture Movements (IFOAM)
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- *Information about organic methods of production and marketing.*

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- *IPM systems for vegetable production; IPM training.*

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- *Information about IPM and biological controls; IPM training.*

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- *IPM consultancy.*

Dr. Paul K. Ndalut
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tel + 254 321 43042
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- *Research into potential natural pest control products.*

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Agriculture and Agri-Food Canada
Research Branch
Pacific Agriculture Research Centre
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Agassiz British Colombia VOM 1AO
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tel +1 604 796 2221
fax +1 604 796 0359
- *Substrates, IPM and biological pest controls for horticulture.*

Prof. Lucio Triolo and Dr Angelo Correnti
Biotechnology and Agriculture Sector
Technology Innovation Department ENEA
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tel +369 304 83607
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- *IPM systems for horticulture.*

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tel + 263 4 575 289
fax + 263 4 575 288
- *Research into alternatives for tobacco.*

Dr. James DeVay
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- *Gliocladium product for controlling damping-off and root rot pathogens.*

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tel +32 15 552 771
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- *Substrate systems for vegetables.*

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- *IPM consultancy.*

Dr. Sam Page
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- *Soil tests to identify nematodes and other pests in IPM for vegetable crops for small-scale growers.*

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tel + 254 2 242 887 or 890
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- *Tagetes extract nematicide.*

Mr. Dermot Cassidy
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- *IPM systems for horticultural crops.*

Grains, Durable Commodities and Buildings

Companies and Research Groups with Expertise in Alternatives

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- *Carbon dioxide for bag-stacks, in-transit carbon dioxide, nitrogen, phosphine, carbonyl sulphide, heat, inert dusts and other post-harvest treatments for grains and commodities.*

Dr. Shiomo Navarro
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Ministry of Agriculture- Agricultural Research Organisation
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- *Hermetic storage systems for grains.*

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Federal Biological Research Center for Agriculture & Forestry
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14195 Berlin
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tel + 49 30 830 4261
fax + 49 30 830 4284
- *Nitrogen flow system and other post-harvest treatments for grains, commodities, textiles, and artifacts.*

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British Colombia V6C 2V6
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- *Diatomaceous earth, commerical pest control product for stored grain.*

Mr. David Mueller
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- *Commercial treatments for buildings eg. food processing facilities.*

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- *Information on carbon dioxide and phosphine post-harvest treatments for stored grains.*

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- *Phosphine and carbon dioxide treatments for stored grains.*

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- *Phosphine and other post-harvest treatments for grains and other commodities.*

Mr. Alfredo T. Gonzales
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- *Commerical phosphine treatments for commodities.*

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fax + 662 381 2022

- *Information on in-transit phosphine, post-harvest treatments for grains and other commodities.*

Mr. Joe Tallon
Vice President
Tallon Termite and Pest Control
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tel + 1 805 366 0516
fax + 1 805 366 0573

- *Commercial treatments for houses.*

Mr. H-W v ROtberg Geschaftsfuhrer
Thermo Lignum
Maschinen-Vertriebs GmbH
Landhausstrasse 17
6900 Heidelberg
Germany
tel + 622 116 3486
fax + 622 120 081

- *Commerical heat/controlled humidity treatments for wood items. artifacts, furnishings, rooms, etc.*

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UK
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fax + 44 181 964 2969

- *Commerical heat/controlled humidity treatments for wood items, artifacts, furnishings, rooms, etc.*

Perishable Commodities

Companies and Research Groups with Expertise in Alternatives

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Oakland, CA 94607
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tel + 1 510 272 8241
fax + 1 510 272 8655
- *Controlled atmosphere transportation systems.*

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- *Heat and other treatments for flowers.*

Dr. Alan Carpenter
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- *Controlled atmosphere treatments for perishable commodities.*

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- *Quarantine treatments for vegetables and flowers.*

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fax + 646 876 8597
email: 100035.3402@compuserve.com
- *Quarantine treatments for perishable commodities.*

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fax + 649 815 4239
email: mlay-yee@hort.cri.nz
- *Quarantine treatments for perishable and other commodities.*

Marketing Manager, Controlled Atmospheres
Permea Inc.
11444 Lackland Road
St. Louis, MO 63146
USA
tel + 1 314 995 3440
fax + 1 314 995 3500
- *Controlled atmosphere transportation systems.*

Dr. John Armstrong
Tropical Fruit and Vegetable Research Laboratory
US Department of Agriculture- Agricultural Research Service
PO Box 4459
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Hawaii 96720
tel + 1 808 959 9138
fax + 1 808 959 5470
- *Heat and other quarantine treatments for tropical fruit and vegetables.*

Dr. Robert Mangan
Research LEader
Tropical Fruit and Vegetable Research Laboratory
USDA- ARS
301 S. International Blvd.
Weslaco, TX 78596
USA
- *Heat and other quarantine treatments for tropical fruit.*

Reports on Alternatives

See books and papers in reference list in this report

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fax + 613 759 7238
email: dunnlab@em.agr.ca

- *Report on heat, phosphine and CO2 experimental fumigation for structures (1996).*

ASEAN Food Handling Bureau
Level 3, G14 & G15 Damansara Town Centre
50490 Kuala Lumpur
Malaysia
tel + 603 255 1088 or 254 4199
fax + 603 256 2787

- *Operations manuals on post-harvest treatments for grains, including carbon dioxide for bag-stacks (1991), in-transit carbon dioxide in freight containers (1995/96) and phosphine (1994).*

Dr. Jonathan Banks
CSIRO Division of Entomology
GPO Box 1700
Canberra, ACT 2601
Australia
tel + 616 246 4201
fax + 616 246 4202
email: michelleh@ento.csiro.au

- *"Agricultural production without methyl bromide- four case studies"- edited by H.J, Banks (1995).*

Mr. Michael Hoest Rasmussen
Danish Environmental Protection Agency
Ministry of Environment and Energy
Stransgase 29
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Denmark
tel + 45 32 660 572
fax + 45 32 660 535
email: michael@mst.mst.min.dk

- *Infomration about phase-out programme in Denmark.*

Mr. J. Henningsen
Head of Environment Quality and Natural Resources
DG XI, European Commission
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B-1040 Brussels
Belgium
tel + 322 296 9503
fax + 322 296 9557

- *"Prospect Report" on performance and costs of alternatives to MB (1996).*

Mr. Steve Gorman
Head, Technology Outreach Section
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tel + 1 819 953 9399
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- *Report on Canadian leadership in developing alternatives to MB (1995).*

Mr. Heinrich W. Kraus
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Federal Ministry of Environment
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fax + 49 228 305 3524

- *Information on government departments able to provide details of pest control methods used for fruit and vegetable production, grains, commodities, structures.*

Food and Agriculture Organisation
Distribution and Sales Section
FAO
Via delle Terme de Caracalla
00100 Rome
Italy
tel + 396 52281

- *"Soil Solarization" FAO Plant Protection Paper 109 (1991);*
- *"Soilless Culture for Horticultural Crop Production" FAO Plant Protection Paper 101 (1990);*
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Appendix 1:

Method for Calculating Costs for Replacing Methyl Bromide

Standard partial budgeting techniques are applicable to the problem of comparing methyl bromide (MB) and alternative treatments at farm or enterprise levels (Rae 1995). This requires that all physical and financial implications of converting from one treatment method to another be identified. It involves four components:

[A] Additional revenue that would result from the change to the new treatment, eg. enhanced yields, improved quality or reduced storage losses.

[B] Revenue that would be foregone as a result of the change to the new treatment, eg. if there are lower yields or quality.

[C] Additional costs due to the change to the new treatment. This includes the direct running costs associated with the new treatment, as well as the conversion and capital costs.

[D] Costs that will no longer be incurred, due to the change. This would include the costs (direct and capital) of operating and maintaining the old treatment, which would no longer be incurred.

The partial budgeting method for determining conversion costs at farm or enterprise level are summarised in table A1.1.

The partial budgeting method requires the following:

- All costs and revenues should refer to the same time period, such as one year, two years, one crop cycle. In the case of grain storage they should also be based on a common physical storage volume.

TABLE A1.1
Method for determining conversion costs.

Additional revenue - foregone costs	**Additional costs - foregone revenue**
[A]	[B]
[D1] direct costs	[C1] direct costs
[D2] capital costs	[C2] capital costs
Total = [A] + [D]	**Total = [B] + [C]**
Net direct cost/benefit of new treatment = [A]+[D] - [B] - [C]	

- Direct costs include costs of all inputs that need to be purchased in each recurring time period or crop cycle. For example, chemicals and labour.

- Capital costs cover all buildings, machinery and equipment inputs required by each treatment, that have a life of more than one time period. Data include the purchase costs and life of such inputs, and are summarised at appropriate interest and depreciation charges per relevant time period.

- Conversion costs that are paid for should generally be included in [C2].

- All the above costs are measured at the farm/enterprise level, and represent the financial implications for that level. Components of the conversion costs would also include costs often borne elsewhere, such as R&D and training.

- Where it is not possible to quantify the effects of alternative treatments on yields, quality and losses, a qualitative assessment of the expected effects should be given.

Appendix 2:

Agenda 21 Commitments to Sustainable Agriculture

The Earth Summit's Agenda 21, signed by governments in Rio de Janeiro in 1992, contains a chapter entitled Promoting Sustainable Agriculture and Rural Development (UNCED 1992). This chapter commits signatory countries to a list of objectives and activities for promoting sustainable agricultural practices, including Integrated Pest Management (IPM) and non-chemical methods of pest control. Agenda 21's section on pest control notes that 'integrated pest management... is the best option for the future' for controlling pests, because it ensures yields, reduces costs, is environmentally friendly, and contributes to the sustainability of agriculture (UNCED 1992:14.74).

The following Agenda 21 commitments relating to sustainable agriculture will assist the replacement of MB:

- **Reviewing and reforming policies:**
  - *Ensure the environmentally safe and appropriate use of pesticides by reviewing and reforming national policies and mechanisms, for example pesticide pricing, IPM policies and action plans;*

- **Implement IPM programmes:**
  - *Implement programmes to put IPM practices within the reach of farmers through farmer networks, farm extension [education and advice] services and research institutions;*

  - *By the year 1998, establish operational and interactive networks (among farmers, advisers and researchers) to promote and develop IPM.*

- **Research:**
  - *Carry out on-farm research in the development of non-chemical alternative pest management techniques;*

  - *Encourage research into pesticides that are target- specific;*

- **Information:**
  - *Consolidate existing information and programmes on pesticides that have been banned or severely restricted in different countries;*

  - *Document and disseminate information on alternative non-chemical ways of controlling pests;*

- **Interdisciplinary networks:**
  - *Establish IPM networks to demonstrate the social, economic and environmental benefits of IPM for food and cash crops;*

- **Regional focus:**
  - *Develop IPM at regional level, taking into account specific regional conditions;*
  - *Strengthen regional interdisciplinary projects;*

- **Training:**
  - *Conduct training programmes in techniques for IPM and control of pesticide use;*
  - *Train farm advisors/educators and farmers in non-chemical ways of controlling pests.*

- **Technology transfer:**
  - *Strengthen national public administrations in the transfer of techniques for IPM.*

Funding mechanisms for Agenda 21 activities are currently under discussion at international level. Progress in meeting the objectives in Agenda 21 will be reviewed by the international community, under the auspices of the Commission for Sustainable Development.

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