Deutscher Tropentag 2002
Witzenhausen, October 9-11, 2002
Conference on International Agricultural Research for Development

Strategy in Ozone Depletion Substances in Agriculture in Developing Countries (Montreal Protocol)

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Abstract

In 1974, the experts of the University of California claimed that the man-made chemicals known as chlorofluorocarbons (CFCs) were damaging the stratospheric ozone layer.

Methyl bromide (MB) and Carbon Tetrachloride (CTC) "represents" the Ozone Depletion Substances (ODS) used in agriculture. MB and CTC are the highly effective fumigants used to control insects, nematodes, weeds, and pathogens in more than 100 crops, in forest and ornamental nurseries, and in wood products. Its primary uses are for soil fumigation, post-harvest protection, and quarantine treatments.

About 2 800 metric tons of methyl bromide each year is used in the world - about 75 percent to fumigate soil before planting crops, about 11 percent to fumigate harvested commodities during storage and export, and about 6 percent to fumigate structures such as food processing plants, warehouses, and museums, as well as antiques and transport vehicles. The remaining 8 percent goes to the production of other chemicals.

There is a similar situation with CTC and another OD (Ozone Depletion) substances used in agriculture.

There is some interest in recovery, reclaiming and recycling technologies to up grade the fumigation and soil preparation methods with focus to phase-out the ODS in agriculture.

However, recovery and recycling technologies are complex and are likely to prove significantly more expensive in terms of installation, operating cost and competence than the fumigation facilities itself. The amendment of the Montreal Protocol specify precise schedules for the reduction and phase out of ODS, there are many advantages in moving straight to viable ODS alternatives rather than trying to recover, reclaim or recycle ODS.

The UNIDO Vienna together with the Institute of Tropical and Subtropical Agriculture, CUA Prague, professional supervision implemented workshop with the field trial on "Alternatives to Methyl Bromide in Soil Disinfection" in the Dominican Republic, held in Santiago de los Caballeros in November 2000. Technicians and farmers from the Dominican R. participated in the field trial.

The UNIDO Vienna together with the Institute of Tropical and Subtropical Agriculture, CUA Prague, professional supervision prepared the project document for the UNDP Executive Committee of the MFI of the Montreal Protocol "Phase-out of the Use of Carbon Tetrachloride (CTC) as Fumigant in Grain Storage in DPR of Korea" Pyongyang, North Korea, March 2002.

The results and piece of information the above mentioned projects are presents.

Key Words: methyl bromide, pesticide, fumigant, environment, Montreal Protocol, developing countries, field test in methyl bromide and carbon tetrachloride alternatives,

I

2 Background of Study

Under The Montreal Protocol of 1991, methyl bromide was defined as a chemical that contributes to depletion of the Earth's ozone layer. The definition was based on scientific data. Accordingly, the manufacture and importation of methyl bromide will be phased out in developed countries as follows: 25-percent reduction in 1999, 25-percent reduction in 2001, 20-percent reduction in 2003, and complete phase out in 2005. In developing countries, consumption will be frozen in 2002 at 1995-98 average levels, followed by 20-percent reduction in 2005 and complete phase out in 2015. Exemptions for developed and developing countries include quarantine, critical uses and certain preshipment uses.

3. *What is Methyl Bromide?*

The chemical name (IUPAC, CAS) for methyl bromide is bromomethane, and it is classified as a alkyl bromide. It is a colourless and odourless gas at normal temperatures and pressures, but the liquefied gas can be handled as a liquid (1.72 kg/l) under moderate pressure. The specific gravity at 0°C and 760 mm Hg is 1.732, with a vapour density of ~3.27, boiling point of 3.6°C (38.5°F), vapour pressure at 20°C of 1400 mm/Hg (at 40°C it is 2600 mm/Hg), and the viscosity is 0.22 centistokes at 0°C. Methyl bromide is readily soluble in lower alcohol, ethers, esters, ketones, halogenated hydrocarbons, aromatic hydrocarbons, and carbon disulphide.

4. Methyl Bromide in practice.

In 1991 methyl bromide (MB) was tentatively identified, as an ozone depleting compound (Chakrabarti and Bell, 1993). In 1992, at the Fourth Conference of the Parties to the Montreal Protocol, MB was officially added to the list of ozone depleting chemicals, and caused its production to be frozen at the 1991 level.

Identifying MB as an ozone-depleting chemical brings it under the jurisdiction of the Clean Air Act, which mandates that any chemical with an ozone depletion potential (ODP) greater than 0.2 be banned starting in 2001. The ODP value for MB has been determined to be 0.65-70. In November 1993, EPA announced that MB was scheduled for phase out in the United States by the year 2001 (USEPA, 1993).

Because of this, there has been renewed interest on the environmental fate of MB. Much research has been devoted to:

- Estimating how much of the MB in the atmosphere is from agricultural fumigation,
- Measuring volatilisation losses under typical field conditions,
- Understanding the processes and factors that affect transport and volatilisation, and
- Identifying potential means for minimising its volatilisation.

One difficulty in determining the importance of MB in ozone depletion is the great uncertainty in the estimates of global sources of bromine. For example:

- It has been estimated that natural bromide-gas production by marine plankton in the oceans contributes 50-80% to the global burden.

- Estimates of MB released from agricultural fumigation range from approximately 15 to 35% (Abritton and Watson, 1992; Singh and Kanakidou, 1993; Khalil et al., 1993; Butler, 1995).

- Recent figures indicate that biomass burning (e.g., burning the rain forests) may contribute up to 30% (Mano and Andrae, 1994).

- It has been suggested that the oceans may act as a net sink, rather than a source (Butler, 1994) of bromine-gases. This means that the oceans would absorb any MB additions to the atmosphere.

- Automobiles may release significant quantities of bromine-containing compounds.

- Questions continue whether MB deposition onto soil and plant material followed by degradation occurs. If so, this may be an important pathway for removing MB from the atmosphere (Shorter et al., 1995).

It appears that agricultural emissions contribute a significant fraction (i.e., 15 to 35%) to the global burden. However, even if MB is no longer used in agriculture, large amounts of bromine-gases will continue to exist in the atmosphere and, therefore, must be considered a natural condition. The above mentioned factors has to be considered already in the planned operations in agricultural technologies (Havrland B, 2000).

5. Alternatives of Methyl Bromide in Soil Disinfection

From the above-mentioned the Methyl Bromide is considered as the most negative chemical agent, which is compiling to the Ozone Depletion Substances (ODS). At present an alternative methods for the Soil Disinfection are tested. A main idea is to avoid the Methyl Bromide in the agricultural technological process. As a soil disinfection material were tested Dazomet (Basamid ® 98% GR), Metam Na (Busan ® 1020, 33% and steam.

The UNIDO Vienna together with the Institute of Tropical and Subtropical Agriculture professional supervision implemented workshop with the field trial on “Alternatives to Methyl Bromide in Soil Disinfection” in the Dominican Republic, held in Santiago de los Caballeros in November 2000. Technicians and farmers from the Dominican R. participated in the field trial. Participant sectors included cut flowers, cantaloupe melon and tobacco production, as well as representatives from the MB and other pesticide and agricultural supplies dealers.

Technical aspects and the results obtained until now were presented, explained in detail and discussed by the technicians responsible for each trial site. In general all small-scale trials were finished with success and the results correctly interpreted. Currently on going commercial scale trials were also introduced.

The production system of each sub-sector was explained and on going commercial scale trials described to the participants. Overall, all sectors involved were very well aware of the need for MB replacement and the coming phase out of MB. They expressed their interest in collaborating and seeking for assistance for a successful transition to MB free agricultural systems.

TRIAL 1: LA VEGA

SITE LOCATION: Agroindustria del Valle S.A., Palo Blanco, Jarabacoa

CROPS: Cut flower (Gayfeather, Liatris)

STATUS

The trial was initiated during the last week in March 2000. Flower harvest start in late June and the crop was finish by late July. Commercial scale trials started in early August 2000, this crop was finished by November 2000.
The treatments were modified due to the availability of materials. A rigid iron structure was locally constructed for steam application. Using this device, that is moved with a tractor, 10 minutes are enough to treat 8 m^2. Taking into account the time spend in moving the steam generator and steaming device, then it is possible to treat c. 30m^2/hour. The steam generator is using 31 L of gas-oil/hour.

TREATMENTS

The treatments were applied during the last week in May after preparing the land. The treatments were as follows:

O. Control
A. MB (80 g / m^2). In the conventional way
B. Soil steaming using equipment and expertise provided by UNIDO.
C. Dazomet (Basamid ® 98% GR; 400 kg/ha).
D. Metam Na (Busan ® 1020, 33% a.i.; 1000 L/ha).

In relation to the optimisation of fumigant application and contrary to what it was recommended elsewhere in previous reports *(sic*. in order to achieve a good fumigation, special care was taken not to damage the plastics and in a correct sealing of the borders...), and following the recommendations of the local vendor's personnel, the Metam-Na and Dazomet treatments were done without plastic mulch. Furthermore, The dosage of Metam Na was too low, considering that a 33% formulation was used (Busan 1020).

Effect of treatments on weeds

Significant differences were found in the total number of weeds grown in the different treatments. All treatments were effective in reducing the number of weeds as compared with the untreated plots. All the alternative treatments were as effective as methyl bromide in controlling weeds. Although no significant differences were found, 16.2% less weeds/m2 were found in the plots treated with steam than in the MB treated plots (Fig. 1).

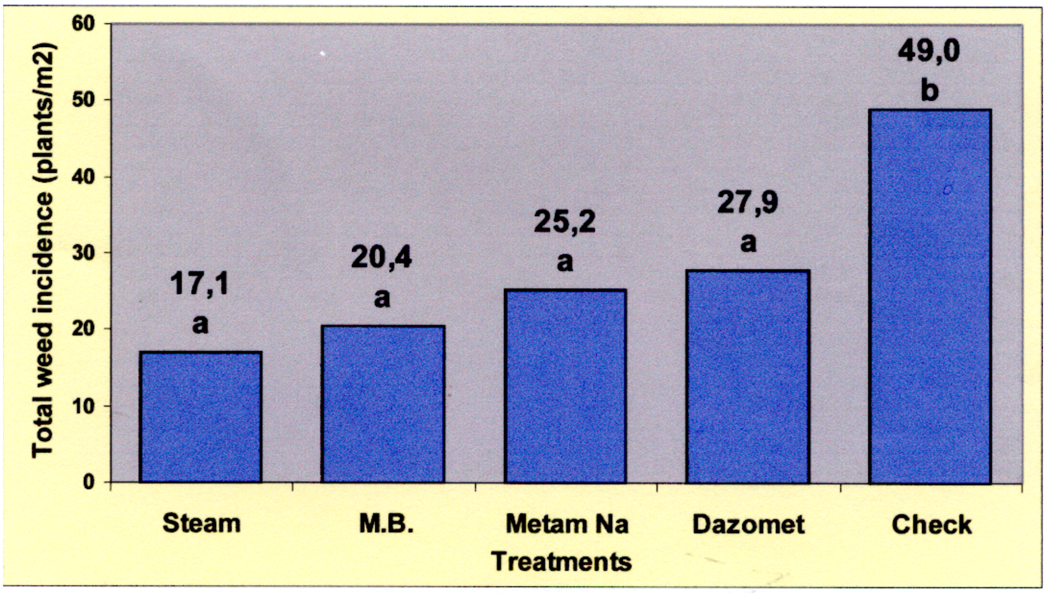

Fig.l. Effect of alternative treatments on total weeds. Cut-flower (liatris) crop at Agroindustria del Valle, Jarabacoa. Treatments with the same letter are not significant different according to a Duncan's Multiple Range Test at 0.01 significance level.

All treatments effectively controlled *Cyperus rotundus,* being as effective as methyl bromide. However, only the steam treatment and methyl bromide were effective in controlling wide leaf (dicotyledon) weeds. Metam Na and steam alternatives effectively controlled long leaf (monocotyledon) weeds including (Fig. 2).

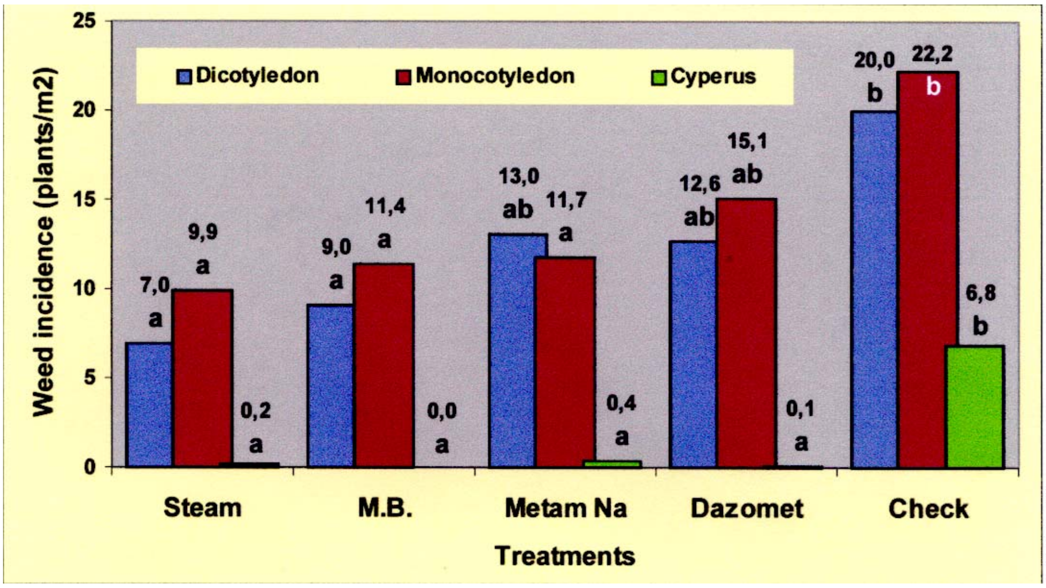

Fig.2. Effect of alternative treatments on weed type and Cyperus rotundas. Cut-flower (liatris) crop at Agroindustria del Valle, Jarabacoa. Treatments with the same letter are not significant different according to a Duncan's Multiple Range Test at 0.01 significance level.

Effect of treatments on plant high

Plant high including inflorescence, was recorded regularly starting one month after plantation that was done on the 20/05/2000 (Fig 3.).

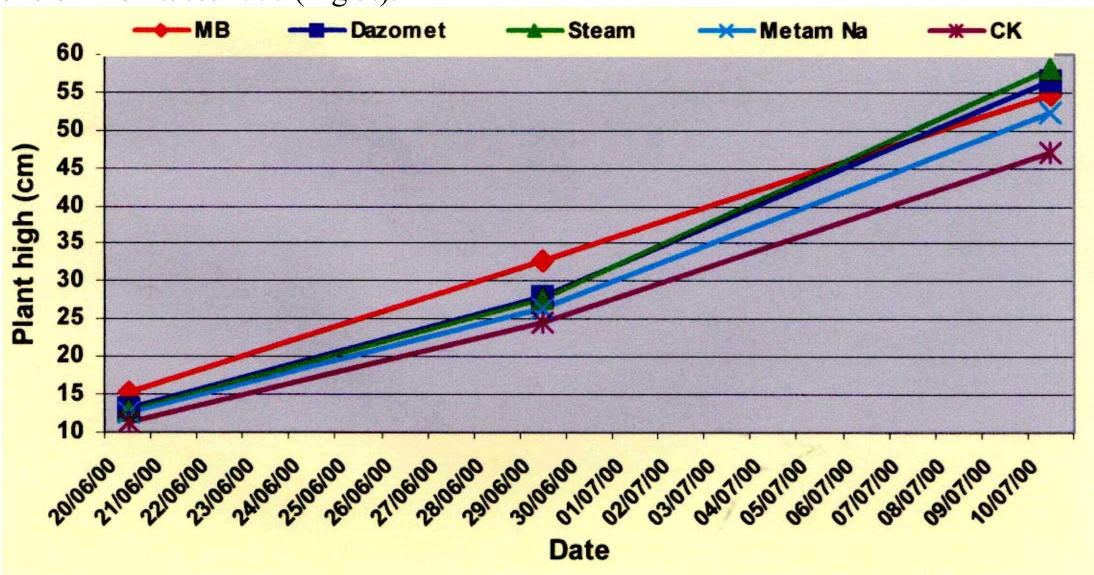

Fig.3. Effect of treatments on plant high, temporal series. Cut-flower (liatris) crop at Agroindustria del Valle, Jarabacoa.

At the time of maximum plant high (10/07/2000) c. 50 days after planting, and before the first flower cut, the alternative treatments dazomet and steam produced higher plants than those grown in the untreated plots. There were no significant differences between the high of plants grown in untreated plots and those in the plots treated with metam Na or methyl bromide (Fig. 4).

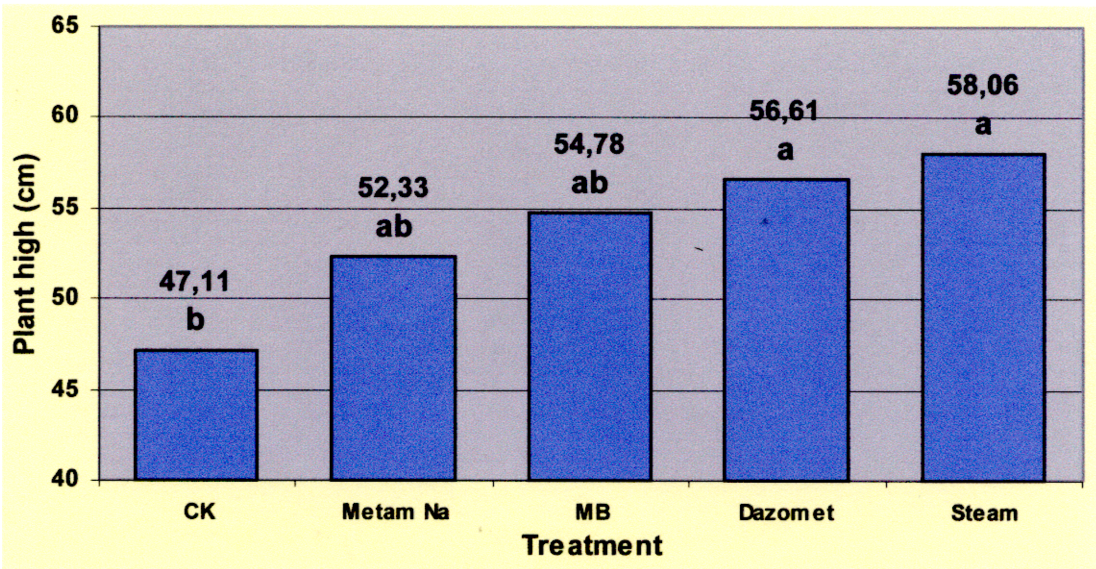

Fig.4. Effect of alternative treatments on plant high. Cut-flower (liatris) crop at Agroindustria del Valle, Jarabacoa. Treatments with the same letter are not significant different according to a Duncan's Multiple Range Test at 0.05 significance level.

In Fig 5, the growth of liatris plant during the crop cycle is shown. When modeling plant growth by fitting the recorded data to a logarithmic model (Fig. 6), the growth trends for the plants in the steam and the methyl bromide treatment were almost indistinguishable. For Metam Na, the plant growth was slower at the beginning of the cycle to end with figures comparable to those obtained with MB by the end of the crop. The growth of plants in the plots treated with Dazomet, was opposite to that obtained with Metam Na; a fast growth at the beginning and low growth at the end of the crop cycle.

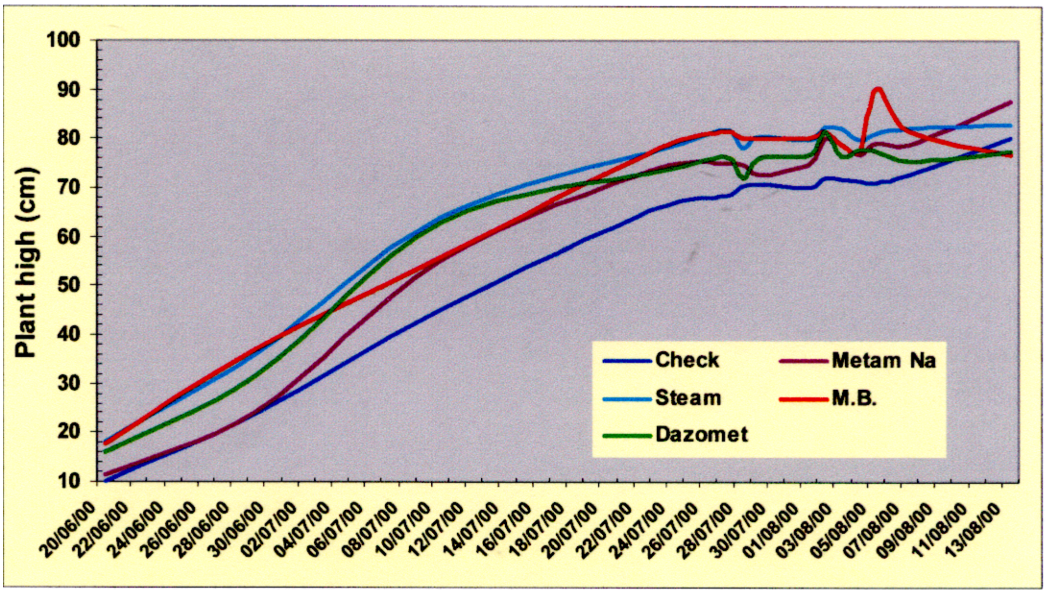

Fig. 5. Liatris growth at Agroindustrias del valle, Jarabacoa. Temporal series

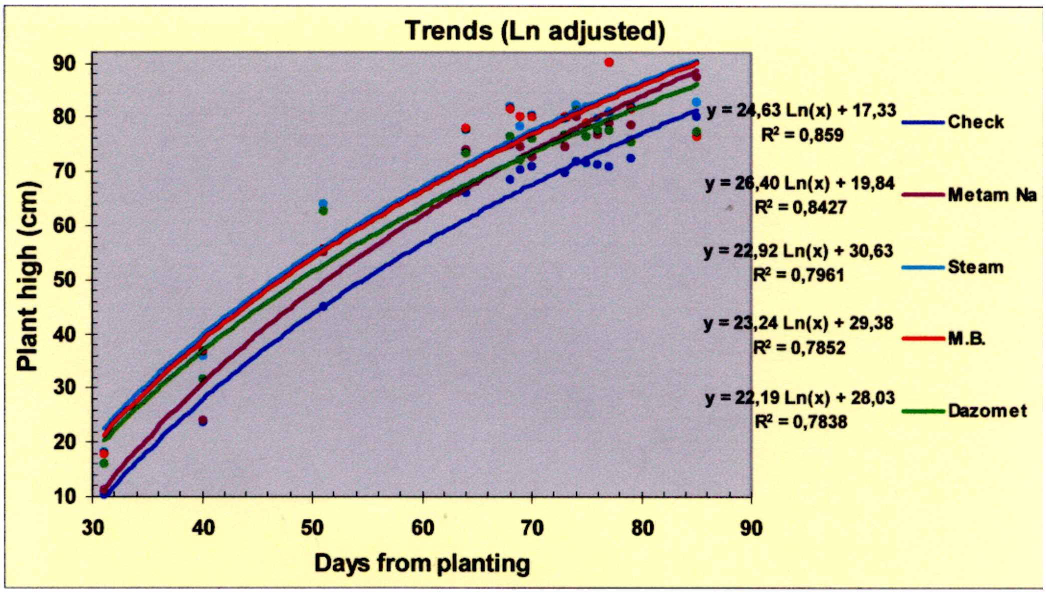

Fig. 6. Modeling liatris growth at Agroindustrias del Valle, Jarabacoa. Neperian logarithm fitting.

The differences among treatments in the average flower size obtained in the first cut (first flower harvest) and that recorded throughout the whole harvest campaign (11 cuts) was preserved. There were no significant differences between size of the plants grown in plots treated with alternatives and those grown in the MB treated plots. The plants grown in steam and MB treated plots were significantly larger than those in the untreated plots (Fig. 7).

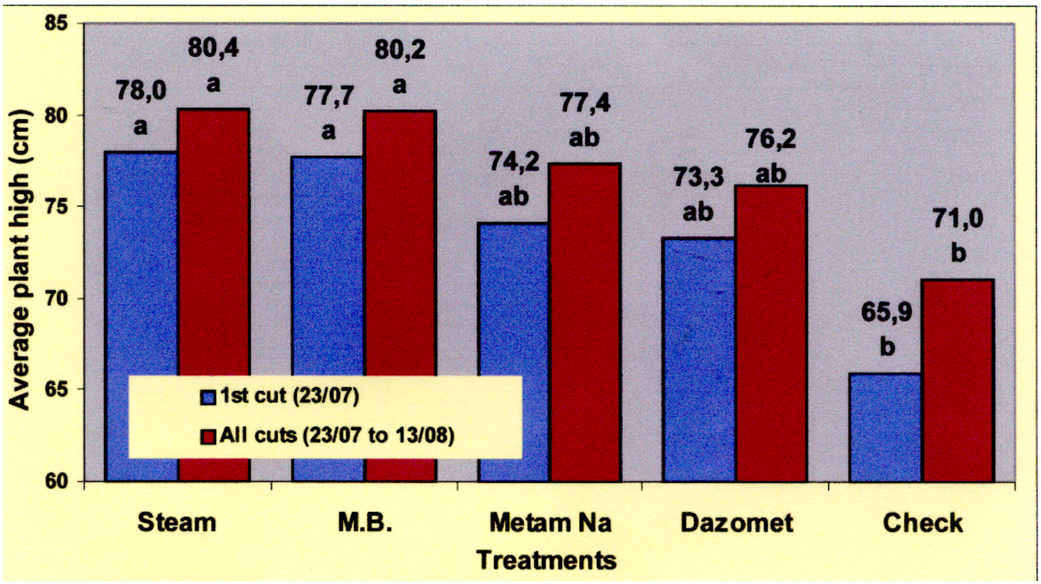

Fig. 7. Effect of alternative treatments on flower size at Agroindustrias del Valle. Treatments with the same letter are not significant different according to a Duncan's Multiple Range Test at 0.01 significance level.

The effectiveness of the fumigant treatments used (dazomet and metam Na) can be further improved if application is optimized. Following the main recommendations can easily do this for when using volatile substances, this is: the use of tarps or plastics to retain the product in the soil and the use of the appropriate dosages of the pesticides.

The follow up field tests are planning in 2002 where will be tested alternatives of Methyl Bromide in soil designation for another cut flowers, strawberries, potatoes, tobacco and water melons.

II

PROJECT TITLE: Phase-out the Use of Carbon Tetrachloride (CTC) as Fumigant in Grain Storage in DPR of Korea

1. PROJECT OBJECTIVE

The objective of the project is to complete the phase out of 150 ODP MT (165 MT) Carbon tetrachloride (CTC) in Korean agriculture (grain storages). CTC is used as fumigant in grain storages as a part of the post-harvest technology to protect grain again pest organisms. Project has to establish the necessary framework conditions, (institutional activities, legislative and policy approaches, etc.) to ensure a timely and sustainable phase-out of CTC in grain storages. At the same time the project will work to enable the Academy of Agricultural Sciences **(AAS)**, Agrochemicalization Research Institute **(ARI)**, Pyongyang as an implementator of the project and the National Co-ordinating Committee for Environment **(NCCE)** as a National Coordinating Agency to implement storage technologies that: obviate the use of CTC; ensure a long and effective future for the use of the alternative fumigants with perspective to minimized utilization of fumigants by the Integrated Pest Management (IPM) methods.
Methacrifos is selected as the most suitable options for the alternatives to CTC in the grain storage in the DPR of Korea.

2. SECTOR BACKGROUND

The Democratic People's Republic of Korea ratified by accession the Vienna Convention and the Montreal Protocol on 24 January 1995. At the request of the Government of The Democratic People's Republic of Korea, the Ozone Cell of NCCE submitted (December 1996) the Country Programme, a prerequisite activity for assistance from the Multilateral Fund. The Secretariat of the Fund has certified that the DPR Korean Country Programme conforms to the format of the approved guidelines. This 1996 Country Programme has been revised and the 2000 Amendment to the Data in the Country Programme reflects the updated production and consumption data.
The Government of the Democratic Peoples' Republic of Korea emphasises the national importance of the Juche principle of self-reliance in developing its agriculture and industry.

2.1 Background to the Amendment

From 1995 onwards the economic situation in the country has changed dramatically. These adverse effects were mainly due to natural calamities that struck the country in 1995, 1996, 1997 and 1998. These included floods and famines. In 1995 DPR Korea made an urgent appeal to the international community and United Nations for the help for food and other assistance.

Winter 2000/2001 was for DPR Korea a critical season when severe frost (- 30°C) and consequently famine limited the political economy in the country. It is a reason why the figures presenting the ODS production and consumption in the country significantly dropped in some parameters.

The Government, through the shortage of energy, food and foreign currency for the import of pilot raw materials had to re-asses many of its priorities. The result was that many of the projections for production and consumption of ODS from 1996 were deviating from the time schedule of the Country Programme.

The figures from the end of year 2001 and from the beginning of year 2002 indicate particular production reviving in particular industry sectors. The chemical factories in this case will increase production and consequently as well supply the chemical fumigants to the Korean agriculture. The development in the production and consumption of ODS in the country is presented in table 1. The NCCE office confirms the above-mentioned trends.

2.2 Production and Consumption of CTC

Table: 4 CTC as fumigant used in agriculture

Fumigation in agriculture	ODS	1999		2000		2001		2002 *	
		MT	**ODP MT**	**MT**	**ODP MT**	**MT**	**ODP MT**	**MT**	**ODP MT**
Grain Silo fumigation	CTC	240	264	150	165	150	165	170	187
Soil fumigation	**CTC**	200	220	150	165	150	165	130	143
TOTAL		440	484	300	330	300	330	300	330

* Note: amount estimated by NCCE

3. PROJECT BACKGROUND

3.1 Agriculture and Grain Storage in the DPR of Korea

The agriculture of the DPR of Korea presents 16,8 percents of GDP. The agriculture operates on the 1 682 000 ha (2001) arable land (it presents 14% DPRK territory), where permanent crops presents two percents from the above-mentioned area. All agricultural production (through cooperative farms) in the DPR of Korea is controlled and managed by the state. The land with livestock in the DPR of Korea is property of the state. The agricultural production is focused to the crop production where main plants cultivated are: rice, corn, potatoes, soybeans and pulses. From the animal husbandry production it is mainly: cattle, pigs, pork, eggs.

In the country are seven grain storage silos, which in some parameters are approaching world standards in the volume capacity concerned. These silos were designed and built up in the sixties as a part of the post harvest technology for agricultural cooperatives, which cultivate a large area of arable land, or these silos serve as storage silos for the agricultural district or region focused on crop production. One from these silos (Gang So Silo) with the store capacity 7 000 m^3 is located 40 km from Pyongyang. In this out of fashion design silo it is very difficult to provide pests and rodent control. At present, according to the local experts, losses in this silo present 5%. Any reconstruction of this type of silo including installation the up to day ventilation and pest control technology will be costly with limited effect. The grain storage capacity in silos in the DPR of Korea presents volume around 500 000 m^3.

On the cooperative farm in the villages the grain storage technology is realized by the traditional way where some barn on the farm or farmyard serves as a warehouse for grain and another agricultural commodities. As a part of this traditional warehouse is, in many cases, the post-harvest technology unit represented by dehusker machine and cleaning machine on the air cleaning and sieves design base. Through the energetic shortage the above-mentioned equipment is used occasionally. The grain is stored in the bulk form or in the traditional sacks from rice straw. The design of typical village warehouse is divided in two chambers (wings). The chamber for sacks presents store space between 60 to 90 m^3 and between 30 to 50 m^3 for the bulk-stored grain. In the Korean agriculture this design of grain storage presents about 85% of storage capacity.

The economic situation of the country is in direct connection with the Korean agriculture and conversely. The Korean industry including chemical industry is at present not able to supply sufficient amount of the NPK manures, plant protection substances including the substances for pest control to agriculture. In consequence of these facts the efficiency of the Korean agriculture is approximately fifty percent of efficiency in 1992. Nevertheless, the production of cereal has an exceptional priority in the Korean agriculture where activities are focused to the yield and grain storage where mainly pest control is the bottleneck of the cereals production chain.

The total grain storage capacity in the DPR of Korea (warehouses and silos) presents around 3 000 000 m^3.

The cultivated crop area and production figures of Korean agriculture from 2000 and 2001 are presented in table 2.

Table 2: Agriculture of the DPR of Korea in data (2000 and 2001)

DIVISION	unit	2000	2001
Seeding area	1000 ha		
Rice		535	572
Maize		496	496
Wheat and Barley		123	126,7
Potatoes		187	187,7
		Σ 1341	Σ 1382,4
Production	1000 MT		
Rice		1533	2408,6
Maize		1015	1490,8
Wheat and Barley		218	119,3
Potatoes		435	413

3.2 Warehouse (indoor storage)

Two shapes of grain stores are available in the DPR of Korea. One is silo and another one is a horizontal store. The construction of silos is designed for the different capacity and purpose of utilization. The biggest one has a capacity around 7 000 m^3 which presents around 5 000 MT of grain.
The periods of storage depend on the consumption of grain. At present the storage period does not exceed one year. Some cooperative farms have got small stores for temporary storage of grain.
Indoor storage needs the use of fumigants like carbon disulfide or ethylene dichloride with CTC and Methyl Bromide.

Figure 8: Grain Silo in Gangso (7 000 m^3)

Figure 9: Cooperative farm warehouse in village Wan Hwa

3.3 Outdoor storage

Stacks stored outdoors are built on a pallet laid on two concrete or wooden bars, and it is large enough to accumulate more than 15 layers of grain sacks (bags). Covering plastic sheet or straw, weighted down by some suitable weight, protects the stacks. The plastic sheet function is to protect the stacks against rain, humidity and some pests. Usually, the capacity of one grain stack presents around 150 m^3 (100 MT).
For inspection of the grain, some containers filled with fumigants are put under the pallet. The stack of grain to be fumigated could be covered by plastic sheets or by wood boards (traditional method). If wooden boards are used, in this case the sealing is provided by soil heaped on the edges of boards.
Outdoor storages are available for temporary storage of grain in cooperative farms and cereal processing companies.

3.4 Pest problems and pests management

Main pests in grain storage in the DPR of Korea are as follows: *Sitophilus Zeamias, Rhizopertha Dominica, Thribolium Castaneum, Sitotroga Cerealella, Plodia Interpumitella, Paralispa Gulaus, Cadra Cantella, Callosobrachus Chinensis.*
Among them the *Sitophilus Zeamias* and *Plodia Interpumitella* are considered as ones that give the biggest damage in grain storage. The damage by rodent is not ignored either.
Pest management is implemented according to a code of practice. The representative fumigants are the mixtures of carbon disulfide or ethylene dichloride with CTC or Methyl Bromide.
These fumigants are available to be applied for both outdoor and indoor storages.
The dosages of fumigants are different according to the region, climate and storage conditions. The usual rates and treatment durations are mentioned in Table 3.

Table: 3 Fumigant dosage rates and treatment durations recommended for summer and winter conditions by ARI AAS, Pyongyang

FUMIGANT	DOSAGE		DURATION	
	SPRING	SUMMER	< 15°C	> 20°C
CS2 + CTC (1 : 3,6)	350 g/ m^3	150 g/ m^3	60 h	20 h
CH2Cl CH2Cl + CTC (1 : 3)	450 g/ m^3	350 g/ m^3	8 days	5 days
MB	50 g/ m^3	25 g/ m^3	48 h	24 h
HCHO	20 g/ m^3	18 g/ m^3	36 h	24 h
METHACRIFOS	15 g a.i./ m^3	10 g a.i./ m^3	24 h	20 h

3.5 Fumigants and Fumigation

Fumigants are widely used for the control of insects and other pest organisms. In Korean agriculture the fumigants are applied in the soil preparation technology and mainly in the post-harvest technology, particularly in the grain storage technology.
The fumigants have unique characteristics and a great adaptability to the fumigation technique, fumigants can often provide effective, economical control where other forms of pest control are not feasible. In many cases treatments can be carried out on infested material without damaging it in any way.

In the developed countries the development of lightweight plastic sheets to enclose spaces or materials requiring fumigation has extended the use of fumigants and made control procedures easier and much more adaptable. Several modern technological developments, including

instrumentation for gas detection and analysis, improved formulations as well as increased demand for effective and economical pest control measures, have done much to improve fumigation procedures.
Modern technology and research have also brought to light certain problems with fumigants that were previously unknown. Numerous investigations made on both the acute and chronic effects of fumigants have shown that some of these materials are capable of producing serious ill effects on human health. In some cases fumigants with excessive hazard potential have been restricted or prohibited so that they are no longer widely used for pest control in some countries.

In the DPR of Korea, the pest management is implemented according to a code of practice. The representative fumigants are the mixtures of carbon disulfide or ethylene dichloride with CTC or Methyl Bromide.
These fumigants are available to be applied for both outdoor and indoor storages. Carbon disulfide and ethylene dichloride are flammable fumigants. That is a reason why the above-mentioned fumigants are mixed with CTC when are applied as fumigants to the grain storage.

The above-mentioned fumigants were, under special conditions (chemical production shortage), available in the DPR of Korea.
Dosage of ethylene dichloride (CTC) presents 200 grams per m^3. Dosage of carbon disulphide (CTC) presents 300 grams per m^3. The above-mentioned figures presents the CTC consumption (theoretically) around 150 MT per year under pre-condition that the grain stock has been treated only once a year. This figure is valid only for silos (500 000 m^3).

In the DPR of Korea was in 2001 treated in warehouses and silos totally 464 000 MT of grain.

4. JUSTIFICATION OF PROJECT

Three gases are commonly used in grain fumigation in the DPR of Korea. These are: carbon tetrachloride (CTC), carbon dioxide and in a very low volume methyl bromide (MB). All of them are toxic, but MB and CTC are the most dangerous to humans. Besides presenting a serious health hazard, CTC and MB are also known as ozone depletion substances. On 1 January 2010, CTC is to be phased out completely. On 1 January 2015, MB is to be phased out completely. The application of MB as fumigant at present in Korean agriculture is 25 MT.

The Academy of Agricultural Sciences, Agrochemicalization Research Institute is proposing as a new alternative fumigant Methacrifos (viz. chapter 5.1.1) as a substitute of CTC in the Korean agriculture. Investment in replacement of CTC involves finding alternative mean of treatment and securing the future use of the most valuable fumigant, Methacrifos, by upgrading application techniques to ensure complete insect kill and so preventing the development of resistance.

5. PROJECT DESCRIPTION

In order to phase-out the use of CTC in the DPR Korea grain storage sector new procedures for indoor warehousing and outdoor storage facilities need to be introduced. In addition, improvements are needed in storage and pest management procedures to reduce the need for fumigation treatment and to prevent development of insect resistance to Methacrifos. These objectives can be achieved by the provision of appropriate training and necessary materials. The project will have to be phased over a period of four years to enable all grain stocks to be transferred across to the new systems and for the staff to develop both confidence in, and competence, with the new technique.

The project will seek to replace current uses of CTC with Methacrifos and ensure that this is sustainable by taking actions to upgrade the Methacrifos usage to a level where the development of insect resistance to Methacriphos is prevented. The following activity will be undertaken:

- Methacrifos in outdoor storage will be replaced by an improved storage methodology that will facilitate use of Methacrifos as an alternative;

- The procedures and technology for Methacrifos usage for indoor fumigation of sack stacks will be upgraded

- Staff will be trained in rodent control procedures in order to minimize fumigant usage;

- Assistance will be provided to enable a suitable policy framework to be adopted for governmental regulation (phase-out) of CTC.

5.1 Description of the alternatives

Alternatives of the Fumigation of Buildings and Silos is possible divide to the following four classes:

I. Chemical Substitutes:

1) PHOSPHINE	Controls stored product pests
2) METHACRIFOS	Controls stored product insects
3) HYDROGEN CYANIDE (HCN)	Controls stored product pests, rodents.
4) SULFURYL FLOURIDE „Vikane“	Controls beetles, wood-wasps, termites, stored product pests, rodents
5) CARBONYL SULFIDE (COS)	Controls stored product pests, wood-boring pests, fungi
6) OZONE	Controls bacteria, viruses, stored product and soil pests including nematodes
7) GASEOUS PHOSPHINE IN CO2	Controls stored product insects.
8) ETHYL FORMATE	Controls stored product insects (Kills stored insects in a few hours)

9) METHYL ISOTHIOCYANATE (MITC) — Is being studied as a grain fumigant and protectant.

11) CARBON DIOXIDE — Controls stored product pests

II. Physical Control Methods

1) COLD TREATMENTS are generally used to prevent multiplication or reinvasion of pests; they also offer an alternative to fumigation with methyl bromide when a mild non-chemical disinfestations is needed.

2) HEAT TRETMENTS can control as fast as methyl bromide and other fast acting fumigants. They involve heating commodities to temperatures of 50 – 70 °C and cooling them rapidly where necessary to avoid damage. Capital costs are high.

3) IRRADIATION of commodities with gamma rays, X-rays or accelerated electrons is an effective method of pest control, already used in some situations. Further development is hindered by the lack of international agreements regarding trade and quarantine requirements of irradiated products. Consumer acceptance of irradiated food products is another impediment, as is cost.

4) SANITATION AND PREVENTATIVE PRACTICES (physical removal) includes practice such as cleaning, removal of food residues and stock rotation – measures that are part of the normal management of stored durables. The aim of sanitation is to prevent pests from multiplying and to reduce the need for pest control by removing pests or keeping them away from the commodity.

III. Contact Insecticides

Contact insecticides can offer lasting protection. However, they can leave chemical residues on treated commodities and their use is therefore excluded for processed products. Pests also tend to develop resistance to contact insecticides.

1) ORGANOPHOSPORUS COMPOUNDS are widely used as grain protectants. The speed at which such chemicals degrade is highly dependent on temperature and moisture.

2) SYNTHETIC PYRETHRODIS are insecticides, which are quite stable on grain, can be effective for up to two years.

3) BOTANICALS are derived from plants. Many are used in developing countries but there is little incentive for companies in developed countries to register them.

4) INSECT GROWTH REGULATORS (IGRs) are used to protect agricultural commodities. They act by interfering with the life cycle of pests and are not normally able to control adult pests. Their persistence on foodstuffs may limit some of their use.

5) INERT DUST can provide effective, inexpensive, non-toxic and continued pest control in grain. Diatomateous earth is one type of inert dust that has been in widespread use in

grain storages for several years as part of an IPM system. The main disadvantages of inert dust are visible residues and dust problems in the work area.

IV. Biological Methods

1) BIOLOGICAL CONTROL WITH INSECTS OR PARASITES can be an effective method of pest control. However, regulations need to be revised if beneficial insects are not to be considered as contaminants.

2) INSECT PATHOGENS such as bacteria, viruses, protozoa, nematodes and fungi can also be used to help control pests. Some are registered as stored product protectants, but many are still undergoing field tests.

3) PHEROMONES are chemicals that are released by insects in order to control the behaviour of other insects of the same species. It may be possible to control pests via synthetic pheromones either by stimulating or inhibiting specific behaviour patterns, especially mating.

5.1.1 Description of the alternatives applicable in the Korean conditions.

The demonstration projects funded by the Multilateral Fund of the Montreal Protocol and implemented by UNIDO were completed in 2000 in Zimbabwe and Syria. Those projects demonstrated the alternatives to the use of Methyl Bromide, CTC and another OD substances (some recommendations from these Demonstration projects were adopted to this project).
However, the latest research tests and reports from UNEP present Methacriphos as the up to date pesticide for a new millennium. The results offered viable alternatives to the use of CTC in terms of efficacy, safety and cost that will be utilized to implement CTC phase-out in grain storage in the DPR of Korea.

Carbon dioxide, the least used of these gases, is provided in cylinders or by tankers. To ensure a complete kill, carbon dioxide fumigations must be undertaken over relatively long periods, typically at least 15 days. To retain gas for this length of time requires exceptionally gas-tight enclosures and in most situations this is difficult to achieve.

Phosphine is frequently used, as it is convenient, being generated from a solid phosphide formulation, but a fumigation period of at least five days, often seven days, is required. In addition, phosphine has the disadvantage that it cannot be used much below 15°C.

Methacrifos as a new fumigant from the new chemical substitutes was tested and advised by the UNEP authorities recently.
Methacrifos is an organo-phosphorous insecticide with contact fumigant acting against insects and mites with abilities to provide good residual protection.
It is a promising grain protectant as it controls storage pests such as the *Sitophilas* and *Tribolium* species, which are increasingly resistant to other chemicals. A special property of methacrifos is its ability to penetrate grain, thus killing larval stages inside the kernels. It is extremely potent at low temperatures and has a pronounced vapour action. Methacrifos is non-flammable.

Treatment recommendations are as follows:

- Disinfections of stores, in the spray form; dosage: 20 – 50 g a.i. per 100 m^2 of wall and floor surface, or dosage: 10 g a.i. per 100 m^3 of warehouse space. As technical device for the stores disinfections the ultra low volume (ULV) atomizer or fine- mist generator are applied. The thermal foggier is for this operation not convenient.
- Bags (sacks) and stacks are sprayed or dusted with dosage: 50 – 200 g a.i. per 100 m^2 of surface area. The rates give 3 – 8 weeks protection. The dosage 200 grams should be applied only if organo-phosphorous resistant insects have to be controlled.
- Bulk stored grain in silos can be protected for up to 12 months by spraying the grain in the conveyer system using a calibrated applicator set at dosage: 10 – 15 g a.i. per 1000 kg (10 – 15 ppm). In the simple storage bins, methacriphos can be admixed with the bulk grain by spraying or dusting the grain surface where after each thickness (10 cm) the grain has been added. This is called the "sandwich method" of application, used when organo-phosphorous – resistant insects are to be controlled.
- For direct admixture of a liquid insecticide such as methacriphos a device such as a metering pump sprays the chemical onto bulk grain moving in a supply conveyer system. A metering pump supplies the exact volume of insecticide from a drum to produce a fine spray through nozzles mounted for distribution over the full width of the conveyor belt.

All fumigation treatments were observed to give 100% kill.

If **carbon dioxide** will be used to treat full size grain stock, it would need to be provided in large quantities (about 0.75 MT per 250 MT grain stock). In this case, this would require delivery by tanker. Tanker delivery of carbon dioxide is not currently possible in the DPR of Korea.

Phosphine – generating formulations are easy to obtain, convenient and relatively cheap. Nevertheless, with respect to the fact that the climate in Korea display not so high average temperature (except summer) during a year phosphine seems to be not convenient for the Korean conditions as well. (volatility of phosphine is below 15°C limited)

Methacrifos - It is a promising grain protectant as it controls storage pests such as the *Sitophilas* and *Tribolium* species, which are increasingly resistant to other chemicals. A special property of methacrifos is its ability to penetrate grain, thus killing larval stages inside the kernels. It is extremely potent at low temperatures and has a pronounced vapory action.
Methacrifos seams to be from the above presented fumigants the best solution as alternative chemical, which will substitute CTC in the Korean agriculture. In this case the phase-out the use of CTC in grain storages in the DPR of Korea could be initiated.

5.1.2 Description of the alternatives adopted

i) Ground sheets and base sheets

The use of ground sheets and base sheets is probably one of the main preconditions for the fumigations despite the windy conditions. This should form an important component of future fumigation technique.

ii) Pallets

The use of pallets between the first and second layer of sacks has proved feasible and should reassure fumigation staff that fumigation will go through the each sack. Typical outdoor stacks (150 MT) could be built with two pallets one on each of the long sides of the stock. The pallet height should not be more than 120 mm.

iii) Fumigation to use

The main advantage of Methacrifos is its universality where is able control the main range of pests in the grain storage with the low dosage rates (10 g/ m^3) and treatment duration 24 hours. It is a promising grain protectant as it controls storage pests such as the *Sitophilas* and *Tribolium* species, which are increasingly resistant to other chemicals. A special property of methacrifos is its ability to penetrate grain, thus killing larval stages inside the kernels. It is extremely potent at low temperatures and has a pronounced vapour action.

Methacrifos is distinguished by its performance and universality both for indoor and outdoor storage and as well soil preparatory fumigant.
Methacrifos is mentioned as a fumigant of the new millennium.

5.1.3 Fumigation in outdoor storage

The following approach is required to enable the safe adoption of methacrifos fumigation in outdoor stacks.

- Each stack will be constructed on a polythene base sheet (50 μm) and ground sheet (125 μm)

- A tailored, polythene sheet (125 μm) should be placed over the stack as an inner liner to the fabric cover. This is to prevent any water entering as a result of leakage at the seams from the cover and to ensure gas-tightness.

- Outdoor fumigations will take place at the time the covers are put on (August, September), so that temperatures are high enough for good fumigation. Fumigation performance will be verified by measurement of gas concentrations. A record of the gas concentrations will be kept as evidence of fumigation performance. Thanks methacriphos properties the fumigation could be undertaken in the cold winter conditions.

- Once stacks have been successfully fumigated (this is verified by gas measurement) they will be completely free of insects. If covers remain intact and in place, then stack will not be re-infested by insects. Therefore, covers will never need to be disturbed for grain sampling and, in particular, no holes need to be made in the covering sheets. However, stacks will need to be inspected very frequently to check for any damage to covers. In case where holes are made in sheets by rats etc, then sheeting will need to be fully repaired using glue and spare sheeting and, where the polythene liner has also been damaged, a precautionary fumigation undertaken as soon as weather conditions permit. The majority of stacks will remain completely undisturbed from the time that they are fumigated to the time that the grain is moved from the storage site.

Implementation of the new outdoor storage procedures will need to be phased because it is only cost-effective to apply the new procedure to grain that is coming into store. Thus until all old grain has been discharged there will remain a portion of grain maintained under old procedures. It will take about two years for all the old grain to be replaced.

5.1.4 Fumigation in indoor storage

The gas-tightness of indoor fumigations should be improved by building the bag stacks on a polythene base sheet (50 μm). The cover sheet and base sheets will be rolled together at their edges and weighted down by weight. The gas concentrations in all fumigations will be monitored to verify that the fumigation has been successful. A record of the gas concentrations will be kept as evidence of fumigation performance.

In silos the situation with the new coming fumigant (methacrifos) will be changed. Mainly the post-harvest technology including the grain drying, cleaning technology with the fumigant application kit has to be installed and mounted in a very short term. Only this is a way to minimize loses in silos. On the oldest type of silo used in Korea the nozzles could be additionally mounted for distribution of fumigant solution over the conveyor belt. New measuring equipment and laboratory equipment for pest control are essential for the silos.

5.1.5 Rodent control

In large measure, rodent problems in grain storage are due to inadequate rodent proofing. Inadequate measures/systems of rodent control lead to re-infestation and increased consumption of fumigants. In spite of the fact that the rodent control systems does not qualify as an incremental costs (it should be in place anyway) this issues will be addressed during the training programme.

5.2 Phase out schedule

Table: 4 Phase-out schedule in grain storages in DPR of Korea

CTC phase out schedule				
	2002	2003	2004	2005
Tons phase out	0	40	55	55
TOTAL	**0**	**40**	**95**	**150**

If implemented as scheduled the project will eliminate the 165 MT CTC used in storage sector.

5.3 Policy framework

By signing this project document, the Government of the DPR of Korea is committed to:

1) To establish a register of CTC producers (DPRK) and importers and reject any import authorization over the consumption limits (grain storage).
2) To revoke registration of CTC as a grain storage fumigant and ban its use once the project has been finalized.
3) To reduce the aggregate consumption of CTC by the amounts specified above and by 165 ODP MT, by the year 2006.

6. PROJECT INPUTS

6.1 Capital goods

The existing CTC technology does not use base and ground sheets and uses cover sheets that do not have the necessary surface and tightness to avoid contact of stored grain with water vapour when the cover sheets are perforated to extract samples.

The new technology based on the use of ground and base sheets as well as the use of an inner sheet under the cover, as well as two palettes per stack, will prevent contact with humidity and will eliminate the need to perforate the inner liners for sampling. Instead of sampling, the system will monitor fumigant concentration through gas sampling lines.

It is assumed that the new technology will use the existing cover sheets in indoor and outdoor stacks of 100 tons each. The expenses of the sheets together with liners represent 36% of the investment costs.

Materials and Equipment	Quantity	Price (US$)	Total (US$)	Comment
Fumigant meter kits with 200 tubes each	203	1,200	243,600	Enable implementation of new procedure
Gas sampling line	30,000 m	1,2	36,000	Ditto
Ground sheets	750 rolls	50	37,500	Ditto *
Tailored polyethylene inner liners	1,500	135	202,500	Ditto
Base sheets	750 rolls	15	11,250	Ditto *
Pallets	3,000	8.33	25,000	Ditto *
Knapsack-sprayer	1,200	150	180,000	Ditto
Transportation costs at 200 sites			10,000	Ditto
Sub-total			**745,850**	

* Note: (available in Korea)

6.2 Training

Training is required in new storage methods and rodent pest control especially during the first and the second year. Additional activities like workshops, handouts copies, manuals, audio-video production and guidelines for the storage sector will accompany the implementation of the project.

Figure 10: Participants of Workshop at the Agrochemicalization Research Institute of Academy of Agricultural Sciences, Pyongyang

7. PROJECT IMPLEMENTATION

The adoption of new technology and procedures will require the provision of essential equipment including laboratory equipment, the training of staff in new procedures and process of adaption/adoption of these procedures. Training is a key element and a brief schedule for the training courses. The success of the project will depend on the provision of appropriate expertise. It is suggested that the project should be implemented according to the project plan.

The follow up project proposal preparation in "Phase-out the Use of Carbon Tetrachloride (CTC) as Fumigant in Soil Preparation in DPR of Korea" is planned to implement in the fall 2002.

<u>References:</u>

- GONZALEZ PEREZ, José A., 2000 **DEMONSTRATION PROJECT ON ALTERNATIVES TO THE USE OF METHYL BROMIDE IN SOIL FUMIGATION**, UNIDO – Mission Report;

- BELL, A. et al., 1998 **METHYL BROMIDE SUBSTITUTION IN AGRICULTURE,** Plant protection and post-harvest section and Environment Management, Water Energy, Transport, Federal Republic of Germany;
- ALOIS DE LARDEREL, Jacqueline et. al., 1998 **PROTECTING THE OZONE LAYER, METHYL BROMIDE**, UNEP.