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Report on agrochemicals. By Peter Marsh. 12 Broxash Rd LONDON SW116AB.UK.

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1. General outline of the industry. Agrochemicals are artificial substances added to crops to promote growth by interfering with external influences harmful to the plant. They do not include fertilisers. They normally work by destroying, or rendering ineffective, organisms such as insects, weeds and disease-causing fungi that can disrupt plant development. Another sector of agrochemicals is concerned with plant-growth regulators, which aid specific growth aspects which a farmer wishes to encourage - for instance the promotion of branching in fruit trees. Total world agrochemicals sales are about $20bn a year and should grow at some 3 per cent a year in the 1990s, according to analysts'estimates,with particular expansion in less developed nations where use of agrochemicals at present is relatively small. Use of agrochemicals (also called pesticides or crop-protection compounds) is intrinsically connected to the world agricultural industry and also to other aspects of farming supply businesses such as seeds provision, a sector worth about $13bn a year in retail sales.

Agrochemicals supply is dominated by the world's big chemicals companies such as Bayer of West Germany, Ciba-Geigy of Switzerland, Du Pont of the US and Britain's Imperial Chemical Industries. The 14 biggest companies in agrochemicals account for about 75 per cent of world sales, according to estimates (see table in section 2.)

New scientific ideas, in particular biotechnology or the artificial manipulation of genetic fragments in plants by novel techniques, are becoming increasingly important in the agrochemicals industry. By these

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means, the biological growth mechanisms of plants can be altered to make them resistant to insect or fungal attack thus reducing the need for orthodox agrochemicals or meaning these materials need to be applied in smaller quantities. Another idea is to "program' plants by altering their genetic make-up to make them resistant to attack by certain kinds of weedkillers which are normally non-selective. That could have the effect of letting farmers spray on greater quantities of specific weedkillers confident that these would destroy only weeds and would not affect the crops which had been genetically protected. The use of new ideas in genetic engineering to aid agrochemicals application is linked to seeds supply in that seeds containing altered genetic material would need to be provided to work with specific kinds of agrochemicals. In some cases, specific kinds of seeds would develop in a set way (for instance to produce plants resistant to attack by certain insects) without the need for conventional agrochemicals. That explains why many of the top agrochemicals companies have been diversifying into the seeds business in recent years.

Use of agrochemicals has in the past few years often been linked to environmental problems. Many agrochemicals are highly poisonous either to people or wildlife if ingested in large quantities. Manufacturing and storing the compounds can thus sometimes be dangerous. Over application of the materials can also lead to problems if the substances leach into water supplies possibly after running off from fields. There can also be dangers of pesticide residues contained on the leaves or stalks of crops and fruit and which then enter the human food supply. These are problems which the agrochemicals industry will certainly need to address over in the coming decade.

2. The agrochemicals market . These materials can be split into four basic types: weedkillers (also called herbicides); insecticides; fungicides and plant-growth regulators. Of the $[illegible]bn 1988 world market in agrochemicals, the split between the different types is as follows (according to figures from Ciba-Geigy):

	percentage	$bn
Weedkillers	46	9.[illegible]
Insecticides	28	5.6
Fungicides	19	3.8
Growth regulators	7	1.4

The industrialised blocs of W Europe, North America and Japan consume some two thirds of the world's agrochemical production and sales, according to figures from Shell. The breakdown of sales by geographical area is as follows:

	percentage	$bn
N America	28	5.6
W Europe	24	4.8
Japan	13	2.6
Latin America	11	2.2
USSR/E Europe/China	9	1.8
Far East (not inc Japan)	9	1.8
Africa/M East	4	0.8
Australia/N Zealand	2	0.4

National breakdowns are difficult to come by. Figures from Shell, however, are available to give the split between agrochemical sales in W Europe. Out of the total market of $5.6bn in 1988, the following countries accounted for these estimated percentage shares: France-29; Italy and W Germany 1[illegible] each ; UK-12; Holland/Belgium, Scandanavia, Spain-7 each; Greece, Turkey- 3 each; others-4.

Different regions show different characteristics in terms of their consumption of specific agrochemicals types. Hence the non industrialised blocs, which include many tropical or semi tropical areas where insect pests are rampant, are high users of insecticides. The highly developed agricultural industry in N America is, on the other hand, a big user of weedkiller as part of its efforts to removing any possible impediments to high crop yields. W Europe, meanwhile, is the biggest single user of fungicide used to check crop disease, probably due to the relatively high rainfall in this part of the world which is often associated with plant disease. According to Ciba-Geigy, these are the figures for percentage shares in different regions for the specific parts of the agrochemicals sector:

	Weedkiller	Insecticide	Fungicides
N America	36	21	9
W Europe	24	15	39
Japan	9	20	19
E Europe	8	4	11
Rest of World	23	40	22
Totals	100	100	100

The biggest companies in the agrochemicals business are as follows

	est. sales 1987 ($bn)
Bayer (W Germany)	2.0
Ciba-Geigy (Switzerland)	2.0

ICI (UK)	Sales in 1987:$1.6bn
Rhone-Poulenc (FRANCE)	1.6
Du Pont (US)	1.2
Monsanto (US)	1.2
Shell (UK/Dutch)	1.0
BASF (W Germany)	1.0
Hoechst (W Germany)	1.0
Dow Chemical (US)	0.8
Schering (WGermany)	0.8
Sandoz (Switzerland)	0.6
American Cyanamid (US)	0.6

Other significant companies in the business include Unilever (UK/Dutch), Eli Lilly, Rohm and Haas, FMC (US), Kumiai (JAPAN).
Different companies have different strengths in the various areas of crop protection. Thus in weedkillers, Ciba-Geigy is thought to be the biggest company with an estimated 13 per cent of the world market. Monsanto is next with about 9 per cent, followed by Bayer and BASF, both with about 7 per cent. In insecticides, Bayer is the biggest company with some 14 per cent of the market. Rhone-Poulenc is next with 10 per cent. FMC and Hoechst each have about 7 per cent; Ciba-Geigy and ICI each have about 5 per cent. In fungicides, Bayer has 18 per cent of the world market, Ciba-Geigy has 14 per cent; Rhone-Poulenc 10 per cent; Du Pont 8 per cent; BASF and Sandoz about 5 per cent each.

Table A (attached) gives a breakdown of the biggest selling agrochemical products worldwide. The source for this is County NatWest WoodMac, a UK stockbroking firm. It can be seen from this that Ciba-Geigy, the biggest weedkiller company, has two highly important products in this field, Dual and atrazine; Bayer, the biggest insecticide company, has one big selling product in this area - methyl parathion - and is also strongly represented in herbicides. Many of the products in the list are off patent (patents normally last for 17-20 years from the date of invention) and can thus be sold in their generic rather than branded version by companies which copy the chemical formulas from the inventors of the materials.

3. Links with agriculture industry.

In terms of market value, the 14 biggest agrochemical sectors account for roughly three quarters of the total market. They are split down here (source County NatWest WoodMac).

	Value ($bn) in 1987	
Fruit/vegetable fungicides	1.78	
Fruit/vegetable insecticides	1.62	
Maize herbicides	1.54	
Cotton ~~herbicides~~ insecticides	1.54	
Soybean herbicides	1.50	
Fruit/vegetable herbicides	1.40	
Wheat heαrbicides	1.22	
Rice insecticides	1.04	
Rice herbicides	.90	
Rice fungicides	Sales in 1987: $.64bn	
Wheat fungicides	.55	(Total sales of
Maize insecticides	.49	14 sectors is
Sugar beet herbicides	.42	$15.11bn)
Cotton herbicides	.40	

As the above table indicates, most agrochemicals are aimed at the 10 or so major crops in the world, which include maize,wheat, rice, cotton,soybean, sugarbeet, vines, general fruit and vegetables. Some of the principal types of agrochemicals used in these specific market areas are given in section 4. ~~the attached tables (source County NatWest WoodMac).~~

The role of agrochemicals in aiding agricultural production has been profound. Yields in many countries, both in the developed and developing world, have been boosted enormously by application of the materials. Yet even today for many crops more than a fifth of potential yield is lost due to weeds, insect attack or fungal disease which, in theor/ at least, could be prevented through agrochemicals. Yield losses in major crops worldwide are given in the following table (source UN Food and Agriculture Organisation):

	Total losses (per cent)	Due to:weeds	disease	insects
Wheat	24	10	9	5
Rice	48	11	9	28
Barley	21	9	8	4
Oats	27	10	10	7
Millet	37	13	10	9
Rye	20	15	3	2

Data on some of the main crop types for which agrochemicals are applicable are given here (source County NatWest WoodMac)

All data for 1987 (Source County NatWest WoodMac)

MAIZE

Cultivated area (m ha). Of which:		Herbicide use ($m)	Insecticide use($m)
US.	24	875	220
Europe.	16	340	114
Brazil.	[illegible]	35	30
Rest of N/S Americas.	[illegible]	70	15
Africa.	19	55	21
China.	17	75	58
Others.	17	95	42
Total	**124**	**1545**	**490**

COTTON

	Cultivated area (m ha)	Herbicide use ($m)	Insecticide use ($m)
India	8	4	155
China	5	6	195
US	4	128	260
USSR	3	104	295
Pakistan	2	8	65
Brazil	2	24	60
Others	8	125	510
Total	31	400	1540

WHEAT	Cultivated area (m ha)	Herbicide use (£m)	Fungicide use (£m)
W Europe	17	600	[illegible]
N America	36	250	[illegible]
E Europe	56	180	[illegible]
Asia	79	58	12
Rest	32	132	38
Total	220	1220	[illegible]

SOYBEAN

	Cultivated area (m ha)	Herbicide use ($m)
US	23	1040
Brazil	10	155
China	8	50
Argentina	4	62
India	1	12
USSR	1	2
Canada	1	32
Others	5	129
total	53	1500

RICE	Cultivated area (m ha)	Use ($m) of: Herbicides	Fungicides	Insecticides
India	39	17	15	106
China	33	24	48	123
Bangladesh	10	12	10	40
Indonesia	10	14	11	30
Thailand	8	12	9	25
Brazil	6	23	5	24
Vietnam	6	11	5	15
Burma	5	11	4	10
Philippines	3	14	7	25
Japan	2	590	455	460
S Korea	1	25	54	57
US	1	58	3	21
Europe	1	54	3	30
Others	16	40	11	67
Total	141	905	640	1040

It can be seen from these tables that wide discrepancies exist for use of agrochemicals between different nations with the developed countries generally being far greater users of the materials than nations in the non indistrialised world. Thus for maize the US is responsible for about a fifth of the world's planted area but more than half herbicide use. Europe (which in this table includes USSR) accounts for 12 per cent of area and 22 per cent of herbicide consumption. In the case of cotton the US has 12 per cent of the area and 16 per cent of insecticide use and 30 per cent of herbicide use. Looking at rice Japan has only about 1 per cent of planted area but accounts for more than half total world use of fertilisers and fungicides and slightly half world use in insecticides.

Greater application of agrochemicals is partly responsible for crop yields in many developed nations being better than those elsewhere. It is not of course the only reason - others being wider use of agricultural machinery, more suitable climate etc. However it seems self evident that greater use of agrochemicals in many less developed nations could have a big effect in increasing agriculture yields in these places. It is one reason why many agrochemical suppliers are attempting to step up their efforts in these countries. They see the possibility of a much larger market for their goods in the less developed world than has been the case in the past.

Reasons why agrochemical consumption in less developed nations has to date been much less than in other countries include : lack of awareness of chemicals and of trained manpower in less developed nations; less intensively farmed agriculture systems in which use of agrochemicals does not appear so appropriate; relative lack of availability of many agrochemicals in Third World nations due to absence of local manufacture and small marketing/sales efforts by agrochemicals producers and suppliers; lack of training of farmers and agriculture workers.

Use of agrochemicals among farmers in developed nations is by no means uniform. Much will depend on how keen the farmer is to maximise yields by organising his work around the requirement to arrange for specific sprayings at set times before during and after the growing season for particular crops. The amount of mechanisation on the farm will also affect the degree to which a farmer uses agrochemicals. Applications of these materials is intrinsically linked to equipment including mixing facilities, spraying systems and tractors. If the farmer is to make fullest use of agrochemicals, he will need to invest in such equipment at fairly high levels. He will also need to keep it in good condition. Acting against the general swing towards rising agrochemical use , there has been a trend in some western countries in recent years to stress the possibly unpleasant environmental effects of agrochemicals. This has led with little doubt to a reduction in use of the materials by many farmers on the grounds that they want to minimise the risk of their actions causing environmental problems. Some farmers have gone to the lengths of not using agrochemicals at all - this is part of the so-called organic farming movement in which farmers sell their products with a "pesticide-free" label which they hope will appeal to certain sections of consumers.

Use of the materials for particular crop types will also depend to a large degree on the potency of specific agrochemical classes when used with certain plants. Another factor is selectivity - the extent to which a weedkiller insecticide or fungicide will home in on a specific agent which has a negative effect on a particular plant. Selectivity is all important in the case of weedkillers. A large number of these chemicals kill all plants with which they come into contact. Hence they are of no use in spraying on to fields after germination has started and plants are sprouting or producing leaves. Weedkillers of this type (such as Roundup made by Monsanto or paraquat made by ICI) can be applied only prior to the growing season. Other types of weedkillers differentiate between plant types - attacking only specific weeds and leaving alone a crop such as maize or wheat which the farmer is trying to produce, and can thus be applied all through the growing season. Application of insecticides and fungicides is often effective only when made at specific types of the year, eg when certain pests are at the larva stage or before a particular disease has had time to have a large effect on plant growth. A farmer has to be aware of these times and to organise spraying accordingly. This presses home the idea that agrochemicals' effectiveness is maximised only when a farmer has a high level of knowledge about the interaction between chemicals and plant growth, backed up by the necessary training.

4. Main agrochemical types. Section 3 gave some data about different types of agrochemicals as regards specific crops. The following provides information about the most important kinds of crop protection compounds in terms of scientific classification. Source for data is County NatWest WoodMac.

Herbicide market. Total value 1988 approx $9.2bn.

Triazines. These are the biggest selling herbicides, with 1987 sales of $1.58bn. They are applied to soil and can give selective weed control for a number of crops including maize (the most important crop types for this kind of herbicide) sorghum, sugarcane and pineapple. Big suppliers include Ciba-Geigy, which makes atrazine, a product launched in 1957. It is well out of patent. Sales of atrazine, made by Ciba-Geigy and by other companies which produce generic copies of the chemical, are estimated at $640m ~~$355m~~ in 1987, making it the world's biggest selling agrochemical. Ciba-Geigy also makes chemicals related to atrazine which fall into the triazine class; they include simazine, ametryne and prometryne. Shell, which makes cyanazine, is another leading company. Bayer and Du Pont are seen strong growth in the past but patents on some of the older established triazines have been expiring in recent years, leading to generic copies of the chemicals becoming available at a lower price from companies other than the original developer. Another factory which is expected to reduce sales is heavy competition from rival products. According to County NatWest WoodMac, sales growth rates between 1972 and 1987 were 2.6 per cent a year; sales are expected to decline by 2.7 per cent a year between 1987-1990.

Amides. Est sales $1.06bn (1987) . Mainly used in maize, soybean, rice. Used to stop growth of grasses and broad leaved weeds. Dominant producer is Monsanto . This company in 1966 launched alachlor, which Monsanto sells under the Lasso brand name and which is the biggest selling amide . Another important amide is Dual (generic name metolachlor) made by Ciba-Geigy. Total alachlor sales are estimated at $270m in 1987, making it the world's sixth biggest selling crop protection compound. Other suppliers include Bayer, Rohm & Haas, Schering, Rhone-Poulenc and Shell. 1972-87 growth rate 6.2 per cent a year; expected to decline by 1.3 per cent a year 1987-90.

Carbamates. Est ann. sales $880m. Used for maize , rice, cereals, sugar cane , sugar beet.Biggest producer is ICI; others include Schering, BASF, Rhone-Poulenc and several Japanese companies eg Kumiai, Nissan, Shionogi . Growth rate 72-87 3.6 per cent year: 1987-90 sales not expected to change significiantly. Main products include Eradicane, Sutan, Ro-Neet, Vernam, Tillam , all sold by ICI. ICI gained these products through its acquisition of Stauffer, a US Company, in 1987.

Urea-based herbicides. Market $770m a year. Europe and US account for virtually all the sales: these chemicals little used in Japan. Linuron, sold by both Hoechst and Du Pont , is biggest selling product. Ciba-Geigy is also important. The chemicals are effective at killing young seedling plants following uptake from the soil as they germinate. 1972-87 growth 0.9 per cent a year: market forecast to decline 2.4 per cent a year 1987-90. Biggest urea agrochemical is methabenzthiazuron (brand name Tribunil) sold by Bayer with est ann sales 1987 of $110m.

Toluidines. Sales in 1987 $680m. Used against weeds attacking soybean, cotton, peanuts, cereals. Two major products only in this area, which are Treflan, made by Eli Lilly and American Cyanamid's Prowl (also marketed as Stomp). Ciba-Geigy and BASF have in the past been in the market for these kinds of herbicides but they have ceased manufacture. Market grew at 4.1 per cent a year 1972 -87: expected to decline 3.6 per cent a year 1987-90. Treflan had sales in 1987 est at $320m, making it the world's fifth biggest selling agrochemical.

Hormone weedkillers. Market $535m. Widely used in many crop growth areas. The chemicals were invented mainly after world war two and are mostly out of patent. Dominant type is 2,4-D. Other kinds are known by chemical names MCPA and MCPP. Dow Chemical was a major supplier of 2,4,5-T which has been especially markedly linked with environmental hazards. Market was stable during 1972-87: over the next few years large decline in market expected due to competition from other weedkiller types. 2,4-D, marketed by Vertac and other companies, had sales in 1987 est at $210m, which made it the world's 12th biggest selling agrochemical.

Diazines. A relatively fast growing class,with sales in 1987 of $525m. Sales '72-87 grew by 15 per cent a year:likely to continue growing '87-90 but at a lower rate of some 3 per cent a year. Four major products here:

methazole (brand name Probe) sold by Sandoz: oxadiazon (Ronstar) sold by Rhone-Poulenc: bentazone (Basagran) sold by BASF; pyrazolate (Sanbird) sold by Sankyo. Used to a large degree in rice, cotton, cereals

Diphenyl ethers. Market $430m. Major products are Blazer sold by BASF ,Hoelon (Hoechst), MO (Mitsui) . Class important in Japanese rice market. Recent weedkillers of this sort have included Reflex from ICI, Challenge from Rhone-Poulenc and Cobra from PPG. Market grew at 16 per cent a year 1972-87: will continue to grow, according to forecast, from 87-90 at some 6 per cent a year.

Imidazolinones.Sales 1987 $165m. Three main products, all of them developed by American Cyanamid. They are imazaquin (Scepter); imazamethabenz (Assert) and imazethapyr (Pursuit) . Main outlets are soybeans, wheat, barley. All these products are new to the market: the first, Scepter, was launched only in 1984. They are reckoned to have good growth prospects over the next few years: estimated sales growth 1987-90 is 37 per cent a year. Scepter's sales are thought to be about $150m a year.

Sulphonyl urea herbicides. Sales '87 about $200m. Dominant material is chlorsulphuron (Glean) which is made by Du Pont, the discoverer of this class of agrochemicals. Du Pont put Glean on the market in 1982 and has followed this up with a number of other chemicals of the same class, eg Classic, Canopy, Gemini, Londax, Oust, Express, Harmony, Ally . Sales growth 1987-90 predicted to be about 22 per cent a year. Mainly used in wheat, barley, soybean.

Quaternary ammonium products. The main chemical here is paraquat, brand name Gramaxone, sold by ICI. This is a non selective weedkiller, which kills all plants but is deactivated by soil and so has no long lasting effect. Hence crops can be successfully grown after weed removal with the material. Paraquat is the world's fourth biggest selling agrochemical with sales of $440m.

Glyphosate-type materials. The main product in this category is Roundup, sold by Monsanto, which is the second biggest selling crop protection compound . Annual sales are about $620m. Like paraquat it is non selective. It is also non residual and can be used with a variety of crops. A related material to Roundup is gluphosinate (Basta) which Hoechst has started marketing over the past few years.

Insecticide market. Total sales 1988 $5.8bn.

Organophosphates. Market worth $2.2bn in 1987. This is about a third of total annual insecticide sales. There are about 80 well known materials sold as insecticides which belong to this category. Some doubts about their application due to environmental and handling problems which result from their relatively high toxicity in large doses. Used with virtually all the main crops. Biggest selling compound is methyl parathion, a chemical first sold in 1947 and now marketed by a variety of companies including Bayer. This had sales in 1987 estimated at $480m, giving it the position of the world's third biggest selling agrochemical. Another big selling organophosphate is chloropyrifos (Dursban) sold by Dow Chemical . Leading manufacturers besides Bayer include Sumitomo, ICI, Monsanto and American Cyanamid. Est annual sales [illegible]-87 increased at some [illegible] per cent a year: likely to grow at [illegible] per cent year during 1987-90.

Pyrethroids. Sales in 1987 $1.5bn. Used against cotton and fruit and vegetables in particular. FMC, Shell, Sumitomo and Roussel Uclaf are among the major manufacturers. These materials are based on natural substances in the form of pyrethrum powder extracted from the heads of certain flowers belonging to the chrysanthemum family. Big selling compounds of this type are deltamethrin (Decis) sold by Roussel Uclaf and fenvalerate which is sold under a variety of trade names by Sumitomo, Du Pont and Shell. Other important pyrethroids include Karate from ICI, Rody and Sumi-Alpha from Sumitomo, Mavrik from Sandoz, Baythroid from Bayer. The materials first went on sale in the 1970s and have had good growth rates. Annual growth rates during 1987 to 1990 in terms of sales are likely to be about 8 per cent, according to estimates.

Carbamates. Market in 1987 $1.3bn. Main manufacturers include Rhone-Poulenc, FMC, Du Pont, Mitsubishi, Sumitomo, Hokko, Bayer. The biggest selling product is Sevin, originally sold by Union Carbide. The product became the property of Rhone-Poulenc after the French firm bought the agrochemical interests of Union Carbide in 1987. Sevin was the material made at the Bhopal plant of Union Carbide in India which suffered a catastropic accident in 1984, killing 2,000 people when a cloud of isocyanate gas used in the production process escaped from pipework. Sales in this sector grew at an average of some 3 per cent a year during 1972-87. Forecast growth rate 1987-90, about 1.4 per cent a year.

Organochlorine compounds. Annual sales about $500m. [illegible] group compounds, developed after Second World War and whose use grew strongly in the 1950s. But since then have been associated with environmental problems due to toxicity. Nowadays little used in developed nations for this reason. The materials had been used especially intensively in cotton and maize. Chemicals include DDT, toxaphene, lindane, aldrin, chlordane, endrin. Shell, Velsicol and Rhone-Poulenc are among the makers. Sales are expected to decline markedly over the next few years.

Fungicides. Total market $3.8bn in 1988.

Dithiocarbamates. Sales in 1987 about $810m. Widely used commodity chemicals with many manufacturers. Used against potato blight and other diseases affecting a wide range of fruit and vegetables. Biggest product is Maneb, sold by Du Pont and others . Sales of this some $260m in 1987, making it the seventh biggest selling agrochemical. Other important suppliers include Rhone-Poulenc, Rohm & Haas, Montedison, Bayer, Hoechst. BASF. Sales have been growing slowly in recent years but market now mature and sales expected to decline in the 1990s.

Inorganics. Sales in 1987 some $600m. Espexially important in fruit and vines. Many of these compounds contain sulphur and copper . Main producers include Rhone-Poulenc, Sandoz, CP Chem. Market has been stable or in decline in recent years.

Triazoles. Market in 1987 about $550m. Used widely in orchards, vineyards and field containing cereals, sugar beet, soybeans. Benomyl (Benlate) sold by Du Pont is the most important fungicide in terms of sales, [illegible] est. annual sales of some $280m. Hoechst, BASF and Nippon Soda are also important suppliers. There have been some problems with these chemicals from an environmental point of view. Market during 197[illegible]-87 grew [illegible], at 10.6 per cent a year. Expected to continue to grow, but at smaller rate , at some 4.7 per cent a year 1987-90.

Triazoles. Sales in 1987, $385m. Used in a variety of crops including cereals, fruit, vegetable, vines. Main products include Bayleton, Baynor, Baytan, Bayfidan , all sold by Bayer; Sonax and Topas (Ciba-Geigy); Vital, Radar, Impact (ICI). Launched in more recent years have included Punch (Du Pont) and Systhane (Rohm & Haas). Bayer accounts for about two thirds of total sales in this group, according to estimates. These products were developed only in the 1970s and sales growth is expected to be good in the 1990s.

Organophosphorus materials.Sales 1987 $270m. Used especially in rice, vines, citrus and vegetables. There are just four big selling products in this category. They are Kitazin, sold by Kumiai; Curamil (Hoechst); Aliette (Rhone-Poulenc); Hinosan (sold by Nihon Tokushu Nohyaku Seizo, a Japanese affiliate of Bayer). Sales have been growing in the 1972-87 period at about 6 per cent a year: this is expected to continue over the next few years.

5. Research and development. When agrochemicals first became important after the Second World War relatively little was spent on R&D. The materials were largely simple chemicals produced using uncomplicated manufacturing processes. Today the situation is quite different. The aim increasingly in the agrochemical business is to find new materials capable of destroying weeds, insects or fungi which will have as good as (or better) an effect as past generations of the materials but which have lower toxic effects and which can be applied in smaller doses to minimise environmental problems. Another aim is to make the chemicals more selective so they have an effect only on specific kinds of weeds or other organisms. In recent years, regulations covering use of agrochemicals have become far more stringent, in many developed countries and also in some developing nations. That has had an effect on the manufacturer in forcing more ddetailed and lengthy trials to test suitability of agrochemicals and to ensure that environmental problems are minimised. All these factors push up R& D costs.Nowadays these can easily account for some 10 per cent of. turnover of agrochemical companies. The research costs apply not only to the task of finding new products but also modifying existing products to make them appropriate for new kinds of applications , eg for use in different crop types or fighting new kinds of pests.

The R&D process in many agrochemical companies is extremely laborious; eg at Bayer researchers test some 14,000 new compounds a year to test efficacy against specific crop types. The work is done either in glass houses where different strains of crops can be grown for testing with novel chemicals or, for larger scale tests, in fields.

The costs of this work in terms of developing new compounds can be very high. For instance, it can easily take $60m and about eight years to develop a new agrochemical from scratch, get it through the necessary trials procedures intended to demonstrate acceptable lack of toxicity and environmental problems and then put it on the market at a suitable price for farmers to buy the material in reasonable quantities.

New types of analytical instrument, eg mass spectrometers or highly powerful microscopes, can be used to spot tiny quantitites of material. [illegible] useful in the development procedures. In this way, for instance, researchers can detect tiny quantitites of agrochemical which may remain on crops after they are harvested and turned into food and which may (depending on the specific toxicology characteristics of the chemical) be harmful to health.

Probably about a quarter of the total cash spent on R&D in agrochemicals is pure scientific research, with the rest taken up with the development trials. In the pure research area, scientists are trying to come up with new [illegible] interfering with plant growth action to optimise yields.

It helps here to understand the basics of how most agrochemicals work. Most weedkillers contain chemicals that stop operating vital biological fragments such as enzymes that are contained in plant or animal cells. These are needed if specific weeds or other plants are to grow . In this way , for instance, an agrochemical might bind to a particular chemical site on a specific enzyme. This enzyme might be one that is linked with the process in a plant or weed that takes nutrients from the soil and turns these into energy. The action of the chemical would be block the site, so preventing the enzyme connecting up in a chemical reaction to a protein molecule. That would have the effect of stopping the work of the enzyme, as a result of this preventing the plant gaining the energy it needs to grow. In this way the development of the plant or weed would be severely slowed down.

The obvious point here is that the researcher will want to stop the growth of a weed but would hope that the crop he is interested in protecting would be allowed to grow unimpaired. The chances are that the chemical the researcher comes up with will have a blocking effect on enzymes involved with the development process of both the weeds and the crops, in which case all would suffer. The trick here is to select for blocking an enzyme which is highly important in a weed but (because of the different growth characteristics and metabolic behaviour of different agricultural specimens)is not so important in the crop the researcher wants to grow normally.

For insecticides or fungicides, the strategy is different. The mode of action here is connected with the pest or fungus that poses a nuisance to the crop . It could be that the chemical interferes with enzymes or other biochemicals linked to these organisms' successful development.

The above is a rough explanation of how many of today's agrochemicals work. It does not, however, describe how most of them have been developed. Up until about five years ago there was virtually no possibility of a scientist designing an agrochemical to work in the way described. Rather most agrochemicals developed in the past few decades have come to light by a rather hit and miss technique.Researchers mainly have stumbled upon these materials using a trial and error process to screen thousands , if not millions, of known synthetic chemicals or natural substances for activity in inhibiting a known weed, bug or disease. If they find there is significant activity of this sort, they go on to further stages in development procedures, perhaps modifying the chemical in some way to make it more efficient or reduce any toxic side effects. Only after the substance has been shown to work do the scientists come up with theories - involving mechanisms such as enzyme action etc - explaining how it works.

In recent years, the nature of the research process has changed. Rather than look for new chemicals in this random manner, scientists are more concerned to design compounds to do a specific job. This is summed up under the general title of the customised product approach. Similar trends are also evident in drugs industry research. Scientists have been helped in this general trend by biotechnology which in recent years has become a powerful tool in agrochemical (as well as pharmaceutical) R&D. Biotechnology is the umbrella term for a range of scientific techniques, mostly invented in the last 10 years, for understanding the nature of, and manipulating, gene fragments in plant or animal cells. Using biotechnology methods, a researcher can thus pinpoint aspects of the genetic makeup of the materials in plant cells that control growth of the plant. He can then design a chemical that will interfere with this activity in a set way - such as by blocking sites on enzymes in the fashion described above. In a similar way, parts of the proteins and other biological fragments which control the development of pests which a researcher wants destroyed can be interfered with to stop biological growth and reduce the hazards to crops which the pest might eat or otherwise interfere with. Scientific tools which are important here include computerised modelling equipment, which help researchers to design novel compounds which can be tailored to attack specific parts of the biological fragments.

e. Biochemical crop control methods. Linked with the world of agrochemicals in recent years have been a variety of methods devised to attemot to interfere with the development of plant using biology-based techniques. Some of these ideas stem from the work in biotechnology referred to above. At the root of these ideas are efforts to influence the growth of plants (or to stop the activities of insects and fungi that would have a negative effect on this) by changing the genetic characteristics of plant or animal cells. In this way, for instance, tomato plants genetic characteristics could be altered to make them grow more quickly to produce fast ripening fruit. Another example could be to make the plant secrete a specific substance that is toxic to an insect that normally causes growth of the plant to be stunied. Many of the top agrochemical companies are investigating the possibilities of these biochemical crop control methods. In the future these might be used either independently or with conventional agrochemicals as part of the drive to improve crop yields.

The interest in this area is intrinsically linked to developments in the seeds sector. Until recently seeds production was a fragmented, low-tech area dominated by companies which had grown out of the conventional agrochemical supply industries. The value of traded seeds production each year is thought to be about $13bn. Volume of seeds production is much higher: that is because much use of seeds, especially in Third World countries, comes from farmers producing seed for their own consumption on their own farms.

The notion coming from biochemistry and genetic engineering that seeds can be programmed to grow in set ways has, however, led to many changes in the seeds sector. The idea now is for seeds companies to come up with products that are highly tailored packages of genetic material with specific characteristics and which as a result lead on to plants with uniform aspects to their development. As a result of these theories, many of the big agrochemicals companies have moved in to seeds production in recent years, either through buying up existing smaller companies or through internal research and development. Companies which have moved in this direction include ICI, Rhone-Poulenc, Monsanto and Sandoz. Established seeds companies, including two US companies - Pioneer and Dekalb (which is owned by the pharmaceutical company Pfizer) - have also been investing in biology based techniques to improve their seeds packages. Smaller companies set up in recent years to come up with new biology based methods of plant control include Mycogen, Calgene, Agracetus and Crop Genetics, all of the US, and the UK company, Agricultural Genetics Company. The trend is also being investigated by big food companies such as WR Grace, Kellogg, Nestle and Campbel Soup, all of which are looking at biology control techniques as possible ways of developing uniform crops which could be more useful for processing into food.

There is much excitement in the agrochemicals business about the long term implications of these developments. However it seems likely that few of the techniques will become widely applied before next century. This is partly because of the inbuilt resistance in the agriculture community to new ideas and partly because of the long development times required for many of the new techniques. Also, many in the agrochemicals sector point out that it would be impossible from a practical point of view to transfer to plants all the genes that would be required to make them grow in a natural way. Seen in this light it will be a very long time indeed, if at all, before the need for agrochemicals is supplemented by the new ideas.

Many biological control techniques appear to offer the chance of being more environmentally friendly than conventional methods of crop control using agrochemicals. They are more tied in in many cases to use of naturally occurring biological materials which could have a less disruptive effect on the environment. There is a possible downside as well however. Use of some biological control methods involves the release into fields of some new genetically engineered proteins and other organisms. These could, in theory at least, also interfere with other forms of life - eg mankind or animals - by settling in human or animal cells. For this reason rigorous safety rules during the development stage of biological crop control methods will need to be applied.

In practice biological crop control methods can be split into several areas:

Chemical shielding. This applies to methods to make crops resistant to destruction from specific weedkillers. Seveal herbicides, including Monsanto's Roundup and paraquat sold by ICI, are non selective. In other words they kill all plant life, not just the weeds that the farmer wants to destroy but any crops present on the field as well. That means a farmer has to be careful about when he applies such materials. They obviously cannot be used when his crops have started to grow. That leads to inflexibility in application. The idea of chemical shielding is to build into the genetic structure of plants a gene that is resistant to the action of a specific weedkiller. This would operate by, for instance, adding a particular fragment that blocks the action of a part of the chemical chain in the weedkiller that has the effect of stopping crop growth. If this were done, a farmer would be able to spray on the herbicide confident that only weeds would be killed leaving the growth of crops protected genetically in this way unimpaired. Companies doing research into chemical shielding include Monsanto, American Cyanamid, Rhone-Poulenc and Du Pont. The approach is closely allied to seeds production in that the agrochemical supplier would work closely with a seds developer to ensure that plant seeds of the appropriate type contained the right kind of genetic protection. They would then be used after planting with the specific agrochemical to which they were resistant.

Genetic uniformity. A variation on the above idea is to introduce protection to certain species of a crop. The idea of this would be to ensure that only specific strains of certain plants survived an application of a herbicide, which would kill all the strains a farmer did not want along with any weeds. This would have the effect of ensuring a crop with a uniform genetic makeup , which could be important in food processing and industrial applications. Bayer, the West German company, has been doing research along these lines. It wants to ensure that with oil seed rape, only specific grades of the plant develop. That is important from the point of view of the oil extracted from the crop. Different genetic species produce slightly different oils which may not be suitable for the application the developer of the crop has in mind - eg for use in fragrances, food processing, industrial chemicals. Scientists at Bayer think they may be able to make strains of rape seed that are resistant to Sencor, one of Bayer's big selling herbicides. Spraying this chemical on to a field would thus kill all plant life except for these grades.

Tailored plants. The idea here is to insert genes into a seed that will make a plant grow in a specific way. ICI has had some success in reprogramming tomato plants to produce fruit with ripening characteristics that facilitate canning. For example may [illegible] ripen earlier than normal grades of plant, or produce a fruit that is less squashy than conventional tomatos. Similar ideas are applicable to many other kinds of fruit and vegetable that have to enter the food processing chain after harvest.

Inbuilt insect resistance. Attack by insects or fungi is normally combated by spraying agrochemicals. Often the threat to the plant is not so much the insect itself, unless it actually eats up the plant in a significant way, but viruses that it carries. Calgene, a US company, is one of several biotech businesses looking at the possibility of introducing into plants like cotton segments of biological material that make them resistant to attack by insects such as the bollworm. A variation on this is to introduce a gene that will confer protection against particular viruses that an insect may carry. That is similar in principle to vaccinating people against viral diseases like measles. There is some interest in this approach in protecting plants against diseases such as sugar beet yellow.

Novel modes of attack. This involves engineering through biological processes novel types of chemicals to have the same affect as conventional agrochemicals but which use a different approach. The new approach may well be particularly effective . It also attempts to address the problem that many types of existing insecticide and fungicide are not working as well as in the past due to insects or fungi building up resistant to them - in the same way as [illegible] build up immunity to vaccines. ICI is among several [illegible] using fermentation processes to turn out novel [illegible] of chemicals for such applications. [illegible], a [illegible] company, is working on a new crop control spray comprising a [illegible] that kills caterpillars. The protein is wrapped inside [illegible] of natural polymers and having very fine dimensions. [illegible] poisons the caterpillars as they break through the cell wall [illegible] hopes the product will be on the market in the next few years

Hijacking bugs. This involves harnessing naturally occurring bacteria and other organisms to fight insect attack. Such organisms exist in profusion in nature. It is how many plant species survive attack of this kind using purely their own resources. The idea is to use these organisms to target specific species. Several companies are working on the idea of injecting into naturally occurring bacteria a gene from another bacterium called Bacilius thuringienis. This bacterium exists naturally. It makes a toxin to kill corn borers, insects that damage maize growth. Similar ideas could be used to combat other types of insects which interfere with the growth of other crops.

Worm application. Agricultural Genetics Company, a small UK company in which Ciba-Geigy has a stake, is working on insect control strategies involving the use of tiny worms called [illegible] exist naturally and prey on specific kinds of [illegible]. The plan is to breed large numbers of these [illegible] selective way and then introduce them to fields to [illegible] which a farmer wants to destroy.

7. The future.

Agrochemicals companies generally are fairly optimistic about the 1990s which they reckon should see growth restored to an industry that was somewhat stagnant in the mid 1980s. That would mean the total sales of agrochemicals rise by several per cent a year on the current total revenues of some $20bn annually. Newer , more environmentally friendly crop protection compounds, aided by the slow introduction of the novel biological crop control methods, should give a boost to the industry. Much, however, depends on the state of farming generally around the world. In W Europe and the US agriculture has been in difficulties for much of the 1980s due to overproduction and problems with government payment methods for crops. The problems were made worse by the 1988 drought in the US. There should be particular growth in less developed countries, particularly China, India and other Asian countries. Elsewhere, Eastern Europe and countries in S America like Brazil and Argentina are expected to become more self sufficient in food production and hence increase their use of agrochemicals.

How the industry in all parts of the world is likely to develop in terms of employment opportunities is not known. Also trade statistics on agrochemical use are difficult to come by. But generally supply of these materials is dominated by the industrialised countries. Less developed nations consequently have a large negative trade balance in these substances. Sometimes a problem for many less developed nations is their reliance on companies from the industrialised world for supply and the fact they have few indiginous sources . The picture is slowly changing, however, with some companies from the less developed nations entering into agrochemical production. Such companies and state organisations include NCI in Tanzania , Nargan in Iran, Nitrochlor in Brazil and National Organic Chemicals in India.

end

Table A

WORLD TOP 15 AGROCHEMICAL ENTITIES, 1987

Generic Name	Product Name(s)	Launch Date	Chemical Class	Product Type	Company(ies)	1987 Sales Estimate ($m)	(£m)
Atrazine	atrazine	1957	Triazine	Herb.	Ciba-Geigy, etc	355	640
Glyphosate	Roundup	1972	Organophosphorus	Herb.	Monsanto	345	620
Methyl parathion	methyl parathion	1947	Organophosphorus	Insect.	Bayer, etc	265	480
Paraquat	Gramoxone	1962	Bipyridyl	Herb.	ICI, etc	245	440
Trifluralin	Treflan	1964	Toluidine	Herb.	Eli Lilly, etc	180	320
Alachlor	Lasso	1966	Amide	Herb.	Monsanto	150	270
Maneb	maneb	1950	Dithiocarbamate	Fung.	Du Pont, etc	145	260
Chlorpyrifos	Dursban/Lorsban	1965	Organophosphorus	Insect.	Dow	135	240
Benomyl	Benlate	1967	Benzimidazole	Fung.	Du Pont	125	280
Metribuzin	Sencor/Lexone	1971	Triazine	Herb.	Bayer/Du Pont	120	275
Metolachlor	Dual	1974	Amide	Herb.	Ciba-Geigy	115	210
2,4-D	2,4-D	1942	Hormone	Herb.	Vertac, etc	115	210
Deltamethrin	Decis	1977	Pyrethroid	Insect.	Roussel Uclaf	125	210
Fenvalerate	Sumicidin/Pydrin/ Belmark	1976	Pyrethroid	Insect.	Sumitomo/Du Pont/ Shell	115	210
Methabenzthiazuron	Tribunil	1968	Urea	Herb.	Bayer	110	200

~~Source: CNWM~~

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