SESSION 1

THE TWENTY-FOURTH BAWDEN LECTURE

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SAVING THE PLANET WITH PESTICIDES, BIOTECHNOLOGY AND EUROPEAN FARM REFORM

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The biggest danger facing world wildlife is neither pesticides nor population growth. Naturalists agree that the biggest threat to wildlife in the 21st century is the potential loss of its habitat. Conversion of wildlands into farmland is the major impact of humans on the natural environment, and poses a great threat to biodiversity. About 90 percent of the known species extinction have occurred because of habitat loss. (Edwards, 1995)

Thus, the biggest danger facing wildlife is the potential plow-down of much of the world's remaining forests to produce low-yield crops and livestock. Food needs have always governed the world's land use. Today, our cities take only 1.5 percent of the earth's land area, but farming already takes 36 percent of it. (World Bank Report, 1997)

The world after 2040 must be prepared to feed a peak population of 8.5 billion affluent people. Few of them will be vegetarian. Without higher yields, the world could lose the wild forests and meadows that still cover more than one-third of the earth's surface.

The Green Revolution has been honored for preventing massive Third World famine - but its vital role in protecting wildlife habitat has scarcely been recognized by the public.

If science and technology had not effectively tripled world crop yields between 1960 and 1992, humanity would have plowed approximately 10-12 million square miles of additional wildlands for low-yield crops. (Avery, 1997a)

(In 1992, the world consumed 115 percent of the grain-equivalent calories consumed in 1960. At constant yields, this would have required the conversion of an additional 6.17 million square miles of wildlands - even if the additional land has been as productive as existing croplands. Only a little of the additional land would have been irrigated for top yields; I assumed a 50 percent increase in irrigation from 1960 rather than the 27 percent increase which actually occurred. The additional non-irrigated land would have been poorer, because we're already farming most of the best land. Moreover, most of the additional acres would have been in the Third World, where farmers have gotten far less support from research, infrastructure and government policies. I concluded the additional non-irrigated land would have been only 70 percent as productive as existing croplands.)

This is no precise estimate, but it indicates the enormous magnitude of the natural resources the world would have lost without the Green Revolution: wildlands equal to the total land area of the United States, Europe and Brazil!

Instead, thanks to hybrid seeds, chemical fertilizers and pesticides, we have continued to crop the same 6 million square miles of land, even though we are feeding 80 percent more people, and giving them far more of the resource-costly calories (meat, milk and eggs). In effect, we have tripled the output of world agriculture since 1960 - without taking any more land from nature.

High-yield farming has not only saved land, it has saved the land with the most biodiversity. The best farmlands have the fewest wild species per square mile. (Huston, 1993) Researchers are finding more bird and butterfly species in a few square miles of tropical rain forest than exist in the whole of North America. (Anon, 1997a)

By 2040, we must be able to triple the yields on the world's existing farmland **again**. (McCalla, 1994) Otherwise, we may still lose millions of square miles of wildlands and a huge proportion of our wild species.

Viewed in this light, agricultural research and technology are the most vital investment we can make – for both people and the environment.

THE FAILURE TO SUPPORT AGRICULTURAL RESEARCH

Unfortunately, the world is not gearing up its science and technology resources to meet this conservation challenge.

US funding for agricultural research has been declining for decades in real terms, though the cost and complexity of the research projects continue to rise with the size of the challenge.

The US Federal and State governments spent $1.02 billion on agricultural research in 1970, $1.6 billion in 1980, $1.65 billion in 1990, and $1.8 billion in 1996. Adjusted for inflation, however, the public spending actually **declined** by more than 30 percent. (Huffmann & Evenson, 1993)

US private-sector spending on agricultural research rose in nominal terms from $1.5 billion to $3.15 billion between 1970 and 1990 – but declined in real dollars by 14 percent.

A new study, led by Philip Pardey of the International Food Policy Research Institute, finds that the whole world is currently spending only $15 billion for research to support its multi-trillion-dollar food industry. Worse, the average annual rate of increase in funding slowed from 4.4 percent 1971-81 to 2.8 percent in 1981-91.

Worst of all, the budgets for the Third World's agricultural research centers have fallen sharply. The International Rice Research Institute has lost almost one-fourth of its budget in the last two years, and laid of half of its staff – because every affluent-country donor except Japan has cut back its support for the ongoing Green Revolution.

This is the same agricultural research and technology effort which has saved perhaps **one billion** human lives from famine; increased food calories by one-third for 4 billion Third World residents; and prevented millions of square miles of wildlands from being plowed down.

By comparison, the US has been spending nearly $100 billion per year on subsidies for its farmers. The European Union is currently spending $150 billion per year on its farm subsidies. (OECD, 1995) If we had spent one-tenth as much on agricultural technology in recent decades as we have on farm subsidies, we would have no concerns today about either famine or losing wildlands to food production.

SHOULD WE RECOMMEND LOW-YIELD FARMING?

It is difficult to imagine how a world facing the biggest surge in food demand in history – and which wants to keep its wildlands – needs more research on **low-yield farming**. Yet the environmental movement is recommending organic and traditional farming systems which have sharply lower yields than today's mainstream farms.

A recent organic farming "success" at the Rodale Institute achieved grain-equivalent yields from organic farming that were 21 percent lower, and required 42 percent more labor. (Hanson *et al*, 1997) If the whole world were to accept a 21 percent cut in its current grain yields, it would take an additional 147 million hectares of land to grow our current grain crops. That's 558,000 square miles, nearly equal to the total land area of Great Britain, Germany, France, Denmark, the Netherlands, Belgium and Italy!

The public has been told the organic approach is "kinder to the environment." The public has **not** been told that its low yields would force us to destroy millions of square miles of additional wildlands.

Environmental magazines extol the "virtues" of traditional peasant farming, though its yields may be one-tenth those of modern farming. Meanwhile, the International Center for Forestry Research warns that the planet might lose up to half of its tropical forests to primitive slash-and-burn farming.

Greenpeace and the World Wildlife Fund have gathered millions of European signatures on petitions to ban biotechnology in food production. They do not protest biotechnology in human medicine, to keep more people living longer; but they protest biotechnology in food production to feed them from less land.

FACTORS IN HIGH-YIELD FARMING DISAPPROVAL

We shouldn't be too surprised at the lack of approval and funding for agricultural research:

* The First World countries, which have funded most of the modern farming research, have been surrounded for the past 40 years with highly visible surpluses of grain, meat and milk. Too many citizens now associate the farm surpluses with science, not with ill-conceived farm price supports and trade barriers.

* Western Europe watched its farm population decline from about 20 percent in 1960 to about 5 percent today. This followed an earlier but similar decline in US farmer numbers. Both Europe and America associate the decline of the small family farm with the rise in crop yields, not with the rising value of off-farm jobs.

* Since the publication of Rachel Carson's *Silent Spring* in 1962, First World residents have been bombarded with claims that modern farming was killing wildlife, endangering the health of children, and poisoning the topsoil.

* Perhaps most damaging of all, the First World public has become far more afraid of an overpopulated planet than of famine in faraway places. Dr. Norman Borlaug, awarded

the Nobel Peace Prize in 1970 for his role in the Green Revolution, is now publicly criticized for keeping too many people alive!

(In a letter to the editor of the *Des Moines Register* this year, a reader said that if Borlaug helped save a billion people from famine, he was responsible for the world's overpopulation and pollution). (Anon, 1997b)

STABILIZING POPULATION WITH FOOD SECURITY

Modern medicine and increased food availability lowered the world's death rates, producing a one-time population growth surge. But both also help to restabilize population in the longer term – by giving parents confidence their first two or three children will live to adulthood.

Increased food security, for which crop yields are the best proxy, has been a vital element in sharply reducing world fertility rates. Births per woman in the Third World have already fallen three-fourths of the way to stability since 1965, from 6.1 births to 3.1. The long-term equilibrium for affluent, urban societies seems to be 1.7 births per woman. As a result, demographic trends now indicate a peak world human population of about 8.5 billion people, reached about 2035. (Seckler & Cox, 1994)

The countries that have **raised** their crop yields the **fastest** have generally brought their births per woman down the **fastest**:

* Indonesia has increased its rice yields since 1960 by 250 percent. Its births per woman dropped from 5.5 to 2.9.

* China has tripled its rice yields and quadrupled its wheat yields as it reduced its births per woman from 6.4 to 1.9.

* Zimbabwe has more than doubled its corn yields with Africa's best plant breeding program, while births per woman have dropped from 8 to 3.5.

Countries **without** higher yield trends have kept **higher fertility rates**:

* Ethiopia has suffered famine instead of raising yields even as its births per woman have **risen** from 5.8 in 1965 to more than 7 today.

* Rwanda, where extreme crowding recently helped bring on tribal genocide, has stagnant corn yields and its fertility rate has fallen from 7.5 to only 4.9. (World Bank, 1989)

THERE IS NO "VEGETARIAN SOLUTION" IN SIGHT

If population growth stopped **this hour** we would probably have to double the world's farm output just to provide the meat, fruit and cotton that today's 5.9 billion people will demand in 2030 when virtually all will be affluent.

Humans might be able to meet their nutritional needs with less strain on farming resources by eating nuts and tofu instead of meat and milk. So far, no society has been willing to do so.

America's *Vegetarian Times* published a reputable poll showing that 7 percent of Americans call themselves vegetarians. Two-thirds of these "vegetarians" eat meat regularly, and 40 percent eat **red meat** regularly. Virtually all of them eat dairy products and eggs routinely. Less than 500,000 (.00005 percent) Americans are vegan, foregoing all of the costly livestock and poultry calories. The vegetarian/vegan percentages are similar in other affluent countries.

A similar survey in Great Britain seems to indicate that the chicken has been declared an honorary vegetable.

It will not be possible to stave off disaster for the wildlands with so few vegans, and with even vegetarians consuming large amounts of resource-costly animal and poultry calories – unless we continue to raise farm yields.

Meanwhile, in what used to be the "poor" countries, the demand for meat, milk and eggs is soaring along with the incomes.

* China has been raising its meat consumption by 10 percent annually in the past six years. Chinese consumers are currently eating an additional 5 million tons of meat per year, equal to more than 20 million additional tons of feedstuffs. (USDA/FAS, 1990-97)

* India has doubled its milk consumption (to 65 million tons) since 1980. Two-thirds of its Hindus indicate they will eat meat (though not beef) when they can afford it.

* Indonesia's chicken flocks are expanding at nearly 20 percent per year, as its poultry meat production approaches 1 million tons annually. (USDA/FAS, 1990-96)

To make room for low-yield farming, tropical forests are being burned and plowed, and wild species are being driven from their ecological niches. Indonesia is clearing millions of acres of tropical forest for low-quality cattle pastures, and to grow low-yielding corn and soybeans on highly erodable soils – for chicken feed. World Bank experts say India is getting one-third of the fodder for its millions of dairy animals by stealing leaves and branches from its forests. Forests throughout the tropics are losing up to one-half of their species because bush-fallow periods have been shortened to feed higher populations. (Banerjee, 1994)

THE POTENTIAL FOR HIGHER CROP YIELDS

The world now has only one proven, effective strategy for protecting its wildlands in the 21st century: getting higher yields of crops and livestock from the land we're already farming.

Pessimists have been telling us since the late 1960s that we won't be able to continue raising the yields. In the mean time, we've managed to raise world grain yields by nearly 50 percent. If we'd taken the pessimists' advice to scrap agricultural research when they first offered it, the world would already have lost millions of square miles of wildlife habitat that is still supporting wild plants, wild animals and unique species.

Nor is there any objective indication that the world is "running out of farm technology."

* World grain production hardly increased at all between the 1991/92 crop year (1,706 million tons) and 1995/96 (1,708 million tons). But the strong farm price incentives produced by low grain stocks and high prices generated an extra 150 million tons of grain in 1996/97. Most of the increase came from sustainable farmland in places such as the US, Argentina, and the savannas of Brazil. (USDA/FAS, 1997)

* World corn yields are continuing to rise as they have since 1960, at about 2.8 percent annually, in what's rapidly becoming the world's key crop. (USDA/ERS, 1987) The yield trend has become more erratic - mainly because drought costs more yield in an 8-ton field than in a one-ton field. US corn breeders are now shooting for plant populations of 50,000 plants per acre, three times the current Corn Belt planting density - and 19-ton yields. West Africa has its first high-yield corn varieties, with shorter growing seasons and some bred-in pest resistance.

* The International Rice Research Institute in the Philippines is re-designing the rice plant to get 30 percent more yield. Researchers are putting another 10 percent of the plant's energy into the seed head (supported by fewer but larger stalk shoots). They're using biotechnology to insert resistance for pests and diseases. (IRRI, 1993)

* Meanwhile, traditional breeding programs continue to produce crops with higher yields and greater tolerance for disease and stress. Livestock breeders are getting more milk per cow and a higher percentage of twin calves. Poultry breeders are achieving still-better feed conversion and still-lower death losses. All of these trends will be speeded and amplified by biotechnology.

And if humanity succeeds only in doubling instead of tripling farm output per acre, the effort will still save millions of square miles of wildlands.

Thus, pessimism about agricultural research is an excuse, not a reason, for failing to invest in agricultural research. In fact, the more pessimistic we feel about agricultural research, the more eager we should be to raise agricultural research investments.

The world has obtained strong productivity gains from virtually all of its investments in agricultural research. The problem is that we haven't been investing much.

No wonder that a number of top environmental figures have now begun to endorse high-yield farming themselves, and to recommend increased funding for agricultural research. These converts to agricultural research include Lester Brown, (Brown, 1997) one of the best-known food pessimists in the world, and Jim Downey, Executive Director of Australia's largest environmental group, the Australian Conservation Foundation. (Avery, 1997b)

THE CRITICAL IMPORTANCE OF BIOTECHNOLOGY

Dr Vaclav Smil of the University of Manitoba is one of the world's leading authorities on agricultural productivity. He says that biotechnology is virtually certain to have the same overwhelming importance for agricultural technology in the 21st century as plant breeding has had in the 20th century. And plant breeding has been credited with at least half of the gains achieved from the Green Revolution.

* Biotechnology is the biggest piece of knowledge on humanity's shelves which we have not yet fully exploited. Indeed, we are just beginning to understand its power.

* Biotech radically increases the speed and precision of plant and animal breeding efforts, and thus increases the power of what has been our most powerful high-yield tool.

* Biotech is the only way in which humans can actually use the wealth of genetic biodiversity in our wildlands. Without biotech, we are again restricted to the same tame genes that we've been cross-breeding for more than a century.

Just four examples should suffice to show how vital biotechnology will be to wildlands conservation in the next 50 years:

* *Science* recently noted a potentially huge new breakthrough from biotechnology. Two Mexican researchers have inserted a gene to let crop plants secrete citric acid from their roots. This allows them to tolerate the aluminum toxicity which currently cuts crop yields by up to 80 percent on 30 to 40 percent of the world's arable land. (Anon, 1997c)

* Two Cornell researchers say we're still wasting most of our plant genetic resources by cross-breeding existing crop plants. Instead, they say, we should now be mapping the best gene groups for each trait, from all the genes, in all the species. In effect, we can construct the perfect plant from the ground up. To prove it, they added genes from two wild rice relatives to the best Chinese rice hybrids - and are getting 20-40 percent more yield. In tomatoes, they're getting 48 percent more yield and 22 percent more solids by using some wild genes. Wild genes cannot be put into crop plants without biotechnology as they won't interbreed. (Tanksley *et al*, 1997)

* The International Rice Research Institute and the Rockefeller Foundation have collaborated to produce humanity's first big success against a virus. The new rice varieties will be resistant to the tungro virus that currently robs the world of some 7 million tons of rice production annually. The resistance was created with biotechnology.

* The US Food and Drug Administration is close to approving pork growth hormone - which will produce hogs with half as much body fat and 20 percent more lean meat, using 25 percent less feed grain per hog. Globally, that will be equal to another 20-30 millions tons of corn production per year, produced essentially from laboratory bacteria.

These are just a few of the early examples of biotechnology raising farm productivity. Even the Bt corn and Roundup-ready soybeans, which have drawn so much scorn from Europe's environmental activists, are wonderful examples of high-yield technologies which use some of the safest and most sustainable technologies ever tested by science.

SUSTAINABILITY THROUGH SOIL PROTECTION

Modern high-yield farming is both the most productive and the most sustainable in the history of agriculture.

Throughout history, soil erosion has been by far the biggest problem with farming sustainability. But simple logic tells us that tripling the yields on the best cropland will automatically cut soil erosion per ton of food produced by about two-thirds. It also avoids pushing crops onto the steeper and more fragile acres.

Now, in addition, farmers have used chemical weed killers to invent conservation tillage systems. The US Soil and Water Conservation Society credits these farming systems with cutting soil erosion per acre by **another** 65 to 95 percent. "Conservation tillage" eliminates the moldboard plow, and discs the crop residues into the top few inches of soil. This creates millions of tiny dams against wind and water erosion.

In no-till farming, there is no plowing at all, so the soil is never exposed to the elements. The seeds are planted through a cover crop that has been killed by herbicides.

In addition to saving topsoil, conservation tillage produces far more earthworms and subsoil bacteria than any plow-based system. (Earthworms and soil bacteria hate being plowed.) (Zaborski & Stinner, 1995)

Worldwide, these powerful conservation-farming systems are already being used on hundreds of millions of acres. They are doubling yields in the dryer parts of the Argentine Pampas. They are protecting the productivity of the huge Cerrados Plateau in Brazil. They are adding a third rice crop each year in densely populated countries like Indonesia. They have even been tested successfully in Africa.

The model farm of the future will use still-more-powerful seeds, conservation tillage, and integrated pest management, along with still-better veterinary medications. It will use global positioning satellites, computers and intensive soil sampling ("precision farming,") to apply exactly the right amount of seeds and chemicals for optimum yields – with no excess to leach into nearby streams.

Even then, high-yield farming will not offer zero risk to either the environment or humanity. It will, however, offer near-zero and declining risk, more than offset by huge increases in food security and wildlands saved.

ZERO WILDLIFE RISK FROM FARMING?

For years, the environmental movement has been complaining about the gaps in our environmental accounting – and there are many.

It is now clear, however, that the most glaring gap has been the failure to credit modern farming with the millions of square miles of wildlands preserved from the plow. The environmental movement has been merciless in demanding zero risk from farm inputs and farming systems – while steadfastly ignoring the greatest conservation triumph in human history

It is also clear that the eco-activists know so little about farming that their agricultural recommendations are a danger to the environment. They have pushed ardently for low-yield farming systems - organic and traditional - that would undo most of the environmental benefits of the Green Revolution.

We all want farm inputs and farming systems to become still safer for the environment. But the current risks from farming are already near zero and declining. The environmental magazines in America still shout about twisted beaks and endocrine damage among American waterbirds - but their links are to DDT, PCBs and dioxin. PCBs and dioxin, of course, are not pesticides; and DDT has been banned for decades.

Americans today reckon their farming-related bird losses in thousands, not millions. And the benefits of the high farm yields accrue to billions of birds all over the world.

I understand that in Great Britain only one bird species is regarded as endangered because of pesticides. That bird species is not in danger of being poisoned, but is apparently suffering from a lack of food because insects have been so thoroughly suppressed in the fields. That leaves an environmental dilemma, because the tropical forests, with their millions of species, cannot afford to have the world's good cropland overrun with crop-consuming insects. And Britain wants to keep its birds without sacrificing the tropic wildlands.

Today, modern pesticides, such as glyphosate and the sulfonylureas are applied at low rates (a few ounces per acre), are approximately as toxic as table salt and degrade from the environment in a few weeks. Moreover, these safe, effective chemicals are vastly safer for the environment than biological pest controls.

Biological pest controls are not only the weakest and most erratic of the farmer's pest control weapons, they are clearly the most dangerous to the environment.

Nearly 40 percent of the known species extinction in the world have been caused by invasions of alien species.

As just one example, the European flowerhead weevil was imported and released in America in 1976 - by the Agricultural Research Service - to help stop the spread of European thistle species. Now it is threatening to cause the extinction of three rare native American species: the Platte thistle, the pitcher's thistle and the pictured-wing fly. (Strong, 1997)

Pesticides have not yet caused the extinction of a **single** known species, despite their global use over 50 years. Clearly, the environmental activists have been recommending biological pest control because they hated pesticides, not because biological controls are environmentally safe.

A REGULATORY WELCOME FOR SAFE, SUSTAINABLE HIGH-YIELD FARMING

It is not enough to invest in agricultural research. The world must also have regulators who welcome safe and sustainable new ways to raise farm yields.

At the moment, we do not have such regulators. At the moment, the international regulatory watchword is "cutting pesticide use in half over the next decade." At the moment, government regulators are looking for ways to ban safe farm chemicals, and to constrain farmers with needlessly tight standards on nitrogen in groundwater.

In terms of pesticides, the regulators' heavy-handed and negative attitude toward pesticides threatens to produce more soil erosion, less wildlife, and more human cancer.

America's National Research Council is trying to educate the public that they can cut their cancer risks in half by eating five fruits and vegetables per day. The consumer has no other weapon half so powerful against cancer. And yet the rantings against pesticides have been so powerful and pervasive that some consumers avoid fruits and vegetables for fear of pesticide residues!

Some regulators are even looking seriously at the "precautionary principle," which says there may be some risks we prefer not to run no matter how small they are, because they are politically incorrect. I submit that the environment cannot afford regulation by emotion.

THE CRITICAL IMPORTANCE OF FREE TRADE IN FARM PRODUCTS

To produce the food demanded by 8.5 billion affluent people in 2040, the world must use its best land to the fullest. This not only means raising yields through research and technology, it also means liberalizing farm trade.

The world has a shortage of prime cropland. Asia has the biggest cropland shortage of all. In the year 2045, Asia will have three times as many people per acre of cropland as Europe, and five times as many people per cropland acre as North America.

Asia is currently providing less than 20 grams of animal protein per capita per day for about 3 billion people. The West consumes 65-70 grams. Japan, which recently consumed 15 grams of animal protein per capita per day, is now nearing 60 grams. By 2030, the world will have to supply at least 55 grams of high-quality protein per day for about 4 billion Asians. (FAO, 1992)

But Asia is already using its cropland far more intensively than Western nations. China is double and triple cropping its land where that is possible. China is already using 400,000 tons per year of sheet plastic to lengthen its growing seasons with hothouses, mulching, and transplanted seedlings. South Asia has learned to grow a wheat crop in the dry season between its rice crops. Indonesia is already using all of the good volcanic soils on the island of Java, and is now pushing out onto the poorer soils of its outer islands; it plans to drain one of the world's largest remaining fresh-water wetlands for rice production.

The Orient has already developed far more of its irrigation potential than any other region of the world.

The tropical soils and high temperatures that predominate in Asia have somewhat lower crop yields – and far higher soil erosion risks – than the temperate croplands of the Northern Hemisphere. As one example, the outer islands of Indonesia get three times as much rainfall as Iowa, have five times the rainfall intensity, and may have only one-tenth as much organic matter in the soil to preserve its structure and prevent erosion. Not only would it take more land on these islands to generate the same amount of food production, it would also displace far more wild species and be far less sustainable.

It would be enormously expensive to triple Asian food production again – both economically and in terms of the tropical forests and tropical wildlife that will be threatened.

Asia has a major proportion of the world's tropical forests – and very little other land that could be developed for crop production. The world's tropical forests apparently have half to three-quarters of all the world's wildlife species. E O Wilson of Harvard found 22 species of ants on one tropical tree – which is more ant species than exist in all of the British Isles.

The world must have free trade in farm products, both to prevent Asian countries from pursuing food self-sufficiency in a misguided search for food security and to release the farm production potential for Europe.

THE JOYOUS, IMPENDING COLLAPSE OF EUROPE'S OLD FARM POLICIES

Western Europe's traditional farm policies were always of questionable economic and social value. They were born of an inward view of Europe rather than any focus on the broader needs of the world. They were fixed on the idea of localized food self-sufficiency as a source of food security, despite the reality that national or regional food self-sufficiency **reduces** real food security in the era of modern transportation. Europes Farm subsidies have been aimed at preserving historic patterns rather than adjusting to the needs of a dynamically changing society.

European farm subsidies have compiled a remarkable list of achievements:

* They have almost bankrupted the world's richest and largest community of nations;

* They have importantly undermined job creation for a whole generation of European youth; and

* They have failed to achieve any of their major goals, despite nearly 30 years of massive spending.

* The farm policies are now blocking the European Union's eastward expansion, necessary to protect all of Western Europe from potential adventurism in the former Soviet Republics.

* Farm trade barriers necessary to maintaining Western Europe's farm price supports stand in the way of saving millions of square miles of wildlands in densely-populated Third World countries.

As the 21st century approaches, the world is making a fundamental transition – from 120 years of "surplus" farmland to an era of urgent farmland scarcity. Western Europe's backward-looking farm policies are completely inappropriate for this coming era.

In this new era, every hectare of the world's good farmland will need to achieve its highest sustainable productivity. Free farm trade is crucial to achieving that high productivity

In most years, Europe's farm policies stimulate farm surpluses and dump them into third-country markets, reinforcing the world's already-fierce political commitment to farm trade barriers. In years of short supplies, the Europeans feel free to ban their own farm exports. These activities exacerbate the normal weather-driven instability of world food supplies and prices.

It was Western Europe's opposition that blocked farm trade liberalization in the Uruguay Round of the GATT. It is European farm programs that are still the main excuse for densely populated, land-short Asian countries to maintain farm import barriers. When asked to lower their farm trade barriers, such countries merely point to Western Europe's variable levies and export dumping.

However, Europe's rural areas have several major comparative advantages:

* Europe's rural areas are very good places to carry on agriculture. Free farm trade would at least keep the rural jobs that have been built up (in both farming and food processing) at such high cost through the Community's past export subsidies. Failing to support free farm trade would destroy those jobs as the international community takes away Europe's ability to subsidize farm exports.

* Rural areas will benefit in the coming decades from non-farm job decentralization made possible through modern electronics and transport. Increasingly, professional jobs will be performed where the professionals choose to live. Many of these professionals (and their decentralized jobs) will be attracted to thriving rural communities that offer pleasant surroundings and healthy farm economies.

* Surging incomes in the Third World now give Western Europe an opportunity to: end its counterproductive price supports and trade barriers; help its commercial farmers through the transition to export market competitiveness; and, help boost its non-farm competitiveness by lowering both its farm budget costs and its workers' food costs.

Europe should be supporting farm trade liberalization – for its environmental benefits, to reduce its own budget burden, and to give Europe's commercial farmers the opportunity to earn more income by profitably exporting to Asia.

However, none of these important realities is driving the imminent collapse of Europe's counter-productive farm policies. The collapse is being immediately driven by a more specific set of events:

First, Europe's quite-legitimate fear of a chaotic Russia is so strong that it will soon take in several large East European countries as buffer states. With them will come at least 4 million additional farmers and 23 million hectares of additional farmland. Much of the land and the livestock, especially in Poland, have been producing relatively low yields. With the stimulus of the CAP's high price supports (and Western European financing for new farm supply centers and agro-processing facilities) the new Eastern members of the EU will quickly modernize and boost their productivity. The cost of the current CAP would probably double within a decade. Neither the new member countries nor the current EU members can afford to pay such a major increase in CAP costs.

Second, the CAP is about to face the world for the first time, without the assistance of America's recently eliminated farm price supports and cropland diversion. It may surprise many to think of US farm subsidies as protecting the CAP. But as the US and the EU waged a trade war over each other's farm export subsidies, the American farm policy essentially set a floor under world commodity prices. **The EU has never had to export its farm products in a market where each additional ton of exports drove the price lower.**

In the past, America was always willing to hold large quantities of commodities (especially grain and dairy products) off the market, and to cut production through diverting up to 60 million acres of its own cropland. This allowed the EC/EU to slip its exports under the US price umbrella. That umbrella is now gone. The EU is about to find out how severely that this will inflate its per-ton farm export costs.

As the CAP collapses, it will certainly carry with it the smaller farm subsidy programs of such countries as Switzerland and Norway. These subsidy programs are already under heavy pressure; they cannot stand in the WTO against the weight of the US, the Cairns Group countries and the European Union itself.

The end of Europe's fixation on farm price supports, cropland diversion, wasteful "biofuels" and low-yield organic farming will be a joyous occasion all over the world, but especially in Europe:

Free trade in farm products will bring joy to West European **commercial farmers**, who will get new opportunities to earn improved incomes by meeting real-world demand for farm products. (This assumes that Western Europe's governments assist their farmers through a transition from their current farm policies.) The farmers' alternative would be to watch the continued erosion of their incomes, as the EU steadily lowers its farm price supports, and reduces farmers' quotas to meet the terms of both the Uruguay Round and the Blair House Agreement.

The collapse of the CAP will bring joy to the **taxpayers** of Europe, who will see the beginnings of relief from much of their governmental cost burden at the same time their food prices decline.

The easing of European food costs and tax rates will help solve Europe's biggest problem – unemployment due to the overly-high social cost attached to new jobs. Thus, it will bring joy to the **youth** of Europe.

The end of Western Europe's bad farm subsidies will also cheer the **farmers of Eastern Europe**, who cannot export the output from farming, one of their region's few comparative advantages. Their farm exports cannot go to Western Europe currently because of its existing surpluses and trade barriers. Nor can much go to other countries, because the few countries willing to accept farm imports are already getting them at subsidized prices from the EU. (The remaining countries are stoutly maintaining farm trade barriers against Europe's export dumping.)

True environmentalists should be most joyous of all, as Europe joins the movement toward free trade in farm products. Europe will help to meet Asia's soaring demand for such high-value, resource-costly farm commodities as dairy products and meat, from land already in farming. This will help save millions of square miles of Asian wildlife habitat from being converted to low-yield farming, much of it on highly erodable soils.

Western Europe's new farm policy should focus on:

* A rapid shift to liberalized farm trade, both for its farmer income potential and its world-wide environmental benefits;

* Reasonable compensation for the European farmers, who have invested on the basis of past European farm policies and who will need assistance in the transition to lower farm land values; and,

* A modest, cautious exploration of partial subsidies for landscape farming, as a way to retain and rebuild the character and beauty of the region's countryside.

ONE OF HUMANITY'S GREATEST ENVIRONMENTAL ACHIEVEMENTS

Such a reformed European farm policy can be combined with additional European investments in high-yield, sustainable agricultural research and technology, and with a broadly-enlightened regulatory understanding of the environmental benefits from high farm yields. Together, such policies could transform European agriculture from a conservation roadblock into a world conservation leader.

Such enlightened policies would transform British and European farming from a costly white elephant into an element of European economic growth. They would transform European farmers from wards of the state into proud and productive economic and environmental contributors.

Conservation-based farm policy reform would likewise transform the public view of British crop protection systems. They would no longer be seen as a symbol of wretched excess and a tool of farm surplus. They would no longer be seen as an inviting target for every environmental activist, political opportunist and empire-building bureaucrat.

Crop protection companies would no longer see their stocks discounted like tobacco companies.

Rather, crop protection would be seen for what it can and should be – one of mankind's greatest environmental achievements, in the most conservation-minded era of human history.

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SESSION 2

NEW HERBICIDES, FORMULATIONS AND USES

Chairman and Session Organiser	DR L G COPPING *Consultant, Saffron Walden, UK*
Papers	2-1 to 2-9

ORGANO-CLAY FORMULATIONS OF ALACHLOR: REDUCED LEACHING AND IMPROVED EFFICACY

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ABSTRACT

New formulations of alachlor were designed and tested by adsorbing the herbicide to montmorillonite clay particles whose surfaces were modified from hydrophilic to hydrophobic by pre-adsorption of organic cations such as benzyltrimethylammonium (BTMA) or hexadecyltrimethylammonium (HDTMA). Alachlor adsorption on clay-BTMA complexes was significantly higher than that observed on unmodified clay or clay-HDTMA. Organo-clay complexes pre-adsorbed with 0.5 mmol BTMA/g clay gave better formulations of alachlor than those pre-adsorbed with BTMA at the full cation exchange capacity (0.8 mmol/g). Slow release of the herbicide to the soil solution maintained the herbicidal activity in the top soil as determined by bioassay using *Setaria viridis* and wheat as test plants. Laboratory and field experiments demonstrated that weed control is improved and extended when alachlor is formulated with organo-clay complexes. The environmental and agronomic applications of reduced leaching of alachlor in the soil profile will be discussed.

INTRODUCTION.

Alachlor is a pre-emergence herbicide widely used for selective weed control in various field and horticultural crops. Based on the combined effects of its sorption and degradation in soils, alachlor was classified as a "leacher" with high potential to leach to groundwater (Yen *et al.*, 1994). Indeed, residues of alachlor and its oxoethane sulfonate degradation product were detected in shallow groundwater in North America (Koterba *et al.*, 1993, Ritter *et al.*, 1996, Thurman *et al.*, 1996) and Europe (Riparbelli *et al.*, 1996). Most detections correlate with the intensive use of alachlor in crops such as corn, soybeans and small grain cereals grown in well-drained soil (Koterba *et al.*, 1993). The risk of contaminating the environment with herbicides or their degradation products has stimulated the interest in developing less hazardous formulations. Herbicide formulations conferring lower movement in soil (Buhler *et al.*, 1994, Fleming *et al.*, 1992), reduced photo-decomposition (Margulies *et al.*, 1992, 1993), and lower volatilization (Margulies *et al.*, 1994) have been reported.

The objective of this study was to develop new controlled release formulations of alachlor which would reduce its leaching in soils. Reduced leaching may also result in improved weed control by maintaining the active ingredient in the top soil above the minimum threshold concentration for a longer time (Schreiber *et al.*, 1987). Since alachlor is poorly adsorbed on clay surfaces (Yen *et al.*, 1994), the surface properties were modified from hydrophilic to hydrophobic by pre-adsorbing suitable organic cations. Substituted quaternary ammonium ions [$(CH_3)_3N^+R$ or $(CH_3)_2N^+RR'$], where R and R' are aromatic or alkyl species, were used. Such modified clay surfaces may better bind the non-polar herbicide molecules, thus reducing their concentrations in the soil solution, and consequently extend their biological activity in the field (Jaynes and Boyd, 1991, Margulies *et al.*, 1994).

MATERIALS AND METHODS.

Sodium montmorillonite, SWy-1 (Mont) was obtained from the Source Clays Repository (Clay Minerals Society, Columbia, MO, USA). Organic cations, benzyltrimethylammonium (BTMA), and hexadecyltrimethylammonium (HDTMA) were obtained from Aldrich (Milwaukee, WI, USA). Analytical grade alachlor (Chem Service, West Chester, PA, USA) was used for making the formulation whereas commercial formulation (EC) (Alanex, 480 g ai/kg, Agan Chemical Manufacturers Ltd, Ashdod, Israel) was used as a standard formulation.

The organo-clay-herbicide complexes were prepared as in Margulies *et al.* (1992), freeze-dried, pulverized with pestle and mortar to pass through a 50 mesh sieve, and stored in plastic bottles at room temperature until used. Alachlor adsorption isotherms were measured in the range of 0-700 μmole alachlor/g of clay-organic complex with BTMA pre-adsorbed at 0.5 and 0.82 mmole/g clay [the cation exchange capacity (CEC) of the clay]. The samples were kept under continuous agitation at 25 ± 1 °C during 24 hours. The supernatant was separated by centrifugation at 20,000*g* for 1 h. Alachlor was extracted from the supernatant using a solvent mixture of ethyl acetate/isooctane (1:10, *V*/*V*) and analyzed by gc.

Leaching studies

Sandy soil (Rehovot, 6% clay; 3.5% silt; 90% sand; <0.1% organic matter; *p*H 7.5) was used throughout the study. Tin columns (10x10 cm surface area, 25 cm height) filled with Rehovot soil were used. Alachlor formulations, were sprayed (2.0 kg ai/ha) on the column surface, then the column was irrigated with 500 m^3/ha. Following 48 h of equilibration, the column was sliced along its length to form two similar parts in which test plants, green foxtail (*Setaria viridis)* and/or wheat (*Triticium aestivum,* cv. Ariel) were sown. Plants were grown in the glasshouse under natural light conditions. Shoot height as determined 16 DAT was used to estimate the herbicide presence at different soil depths. Each experiment was repeated at least twice with 5 replicates in a completely randomized design.

Field trials

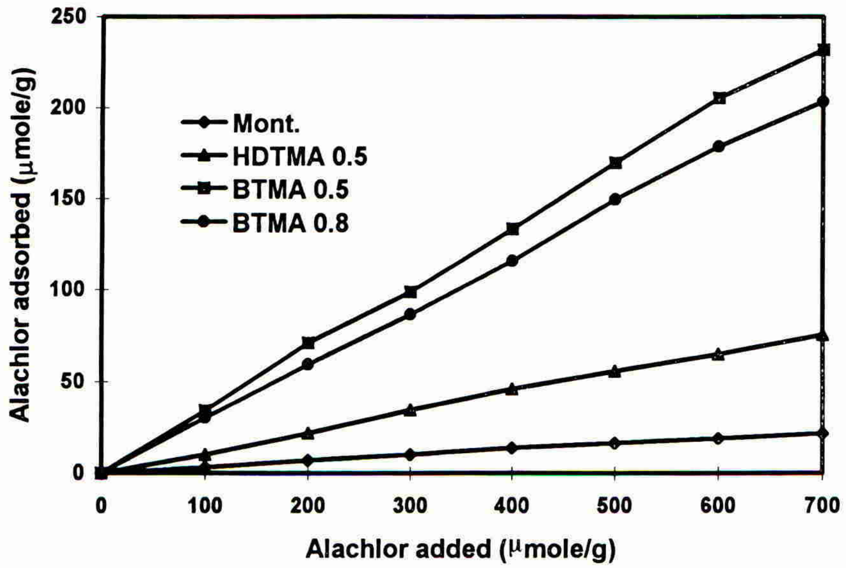
Two field trials were conducted at the Experimental Farm of the Faculty in Rehovot sandy soil. Beds (100 cm wide) were prepared using rotary tiller, and green foxtail (in summer) and wheat (in winter) were sown in two rows, 30 cm apart. Alachlor formulations were applied pre-emergence using a motorized knapsack sprayer. The experiments layout was a randomized block design replicated 5 times, with each plot 1 m wide and 5 m long. The field was irrigated with sprinklers (50 mm) after sowing, followed by additional irrigation or winter rainfalls. Tin columns (see above) were inserted to the upper 24 cm soil layer, dug out and transferred to the glasshouse for alachlor leaching estimation using similar methods described above. Weed control efficacy was periodically evaluated using visual assessments, number of surviving plants and their height.

RESULTS AND DISCUSSION

Alachlor adsorption

The adsorption isotherms of alachlor on clay, clay-HDTMA and clay- BTMA complexes are shown in Figure 1. As expected (Yen *et al.*, 1994), alachlor was poorly adsorbed on montmorillonite alone, whereas adsorption of the herbicide on clay pre-adsorbed with HDTMA resulted in a small increase in the amount of alachlor adsorbed. These data are in agreement with previous results reported by Jaynes & Boyd (1991). Using BTMA as the organic cation significantly increased the adsorbed amount of alachlor, 3-fold more than with HDTMA. Partial saturation of the clay with BTMA at a load of 0.5 mmole/g clay resulted in better alachlor adsorption than that at the full CEC (0.8 mmole/g clay). These data indicate that achieving maximal transformation of the clay surface from hydrophilic to hydrophobic, does not necessarily imply optimal interactions between the herbicide and the organo-clay complex.

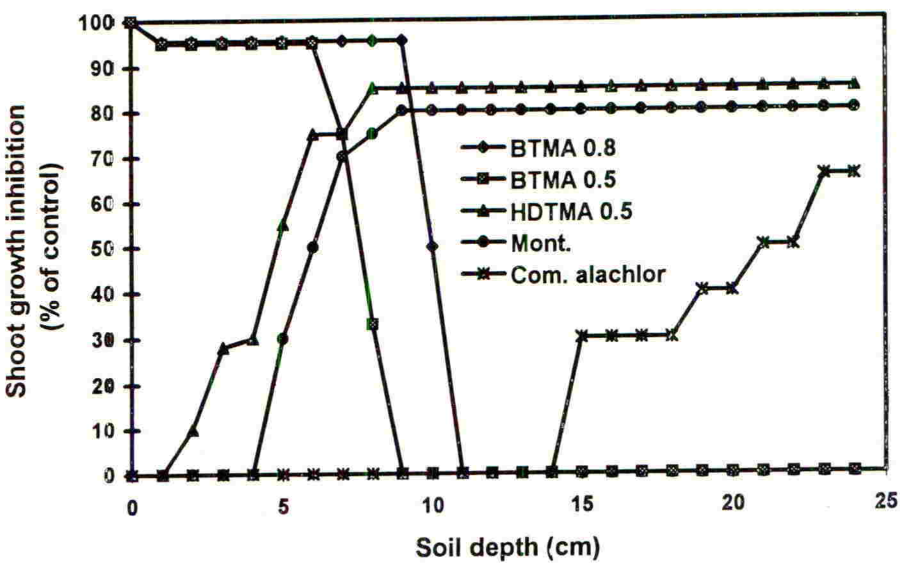
Figure 1. Adsorption isotherms of alachlor on montmorillonite alone (Mont.), montmorillonite pre-adsorbed with HDTMA 0.5 mmole/g clay (HDTMA 0.5), montmorillonite pre-adsorbed with BTMA 0.8 mmole/g clay (BTMA 0.8), montmorillonite pre-adsorbed with BTMA 0.5 mmole/g clay (BTMA 0.5).



Leaching studies

Using Rehovot soil columns, laboratory studies have shown that alachlor applied pre-emergence at the recommended rate (2.0 kg ai/ha), followed by irrigation of 50 mm, leaches to a deep soil layer and in fact disappears from the top 15 cm of the column (Figure 2). Low herbicidal activity was detected at soil depth of 15 to 24 cm, indicating that most of the herbicide applied leached out of the column. Adsorption of alachlor to montmorillonite washed off below the top 4 cm, reduced somewhat the leaching of the herbicide in the soil. When alachlor was formulated with HDTMA-clay complex, improved herbicidal activity at the top soil was observed along with high activity at deep layers (7 to 24 cm deep). Alachlor formulated on BTMA-clay complexes resulted in excellent herbicidal activity confined to the top 8 and 10 cm of the soil column for BTMA 0.5 and BTMA 0.8 mmole/g clay, respectively (Figure 2). These data further support the results presented in Figure 1, demonstrating the relative differences in adsorption of alachlor to the above tested organo-clay complexes. The results also indicate that although the herbicide is strongly bound to the organo-clay complexes, the released amount is sufficient to provide adequate weed control.

Figure 2. Leaching of alachlor (2.0 kg/ha) in column filled with Rehovot soil following irrigation with 50 mm. Green foxtail growth was used to estimate the presence of the herbicide. Alachlor formulations were: Commercial formulation (Com. alachlor); alachlor on clay alone (Mont.); alachlor on clay pre-adsorbed with HDTMA 0.5, BTMA 0.8, and BTMA 0.5 mmole/g clay.



Field trials

The leaching of the commercial formulation applied at 2.0 and 4.0 kg/ha as well as that of alachlor-BTMA 0.5 were estimated 2 DAT following 50 mm irrigation and at 46 DAT after additional 45 mm of rainfall. The results showed that in a sandy soil the commercially formulated alachlor (2.0 kg ai/ha) leaches out of the top 11 cm and accumulates in a layer 11 to 15 cm deep. No significant differences were observed when the herbicide was applied at 4.0 kg/ha. However, the BTMA-clay formulated herbicide retained its activity at the top 6 cm of the soil. When examined 46 DAT, the herbicidal activity of the commercial formulation at both rates was detected only at the very deep layer (22 to 24 cm), whereas the herbicidal activity of the BTMA-formulated alachlor was maintained throughout the top 20 cm layer (data not shown).

Weed control efficacy was evaluated in the field using wheat and green foxtail as test plants. The data presented in Table 1 were taken from the second experiment conducted during the winter of 1996. Weed control efficacy was first evaluated 15 DAT, following the initial irrigation of 50 mm and additional 18 mm of rainfall. The commercial formulation of alachlor applied pre-emergence at 2.0 and 4.0 kg ai/ha provided 54% and 63% weed control, respectively. This level of control declined with time, most probably due to its leaching and degradation as suggested by Yen *et al.* (1994). The organo-clay formulated alachlor (BTMA 0.5), provided excellent and long lasting weed control (Table 1). Evaluations conducted at 15, 33 and 46 DAT have shown that the organo-clay formulated herbicide maintained almost constant level of herbicidal activity. These data indicate that organo-clay formulated alachlor is slowly released in the soil, maintaining the required threshold concentration of alachlor along the control period (Fleming *et al.*, 1992, Schreiber *et al.*, 1987). Further experiments to examine the safety of the organo-clay formulations to major crops are in progress.

In conclusion, the potential use of the new organo-clay formulations of alachlor in weed management practices, may provide effective weed control with reduced herbicide rate and decrease the threat imposed by alachlor to the environment.

Table 1. Weed control efficacy of commercially formulated alachlor and formulated on organo-clay complex (BTMA 0.5 mmole/g clay) applied pre-emergence in a field trial.

	DAT		
	15	33	46
Treatment	Weed control (% of untreated control)		
Commercial alachlor (2.0 kg ai/ha)	54	37	12
Commercial alachlor (4.0 kg ai/ha)	63	41	34
Alachlor-BTMA 0.5 (2.0 kg ai/ha)	99	96	96

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THE USE OF CLOMAZONE AS A POST-EMERGENCE HERBICIDE IN POPPIES (*PAPAVER SOMNIFERUM*)

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ABSTRACT

The herbicide clomazone (trade name Command 480EC) is about to be registered in Australia. Registrations already exist in a number of other countries including the United States and New Zealand. All current registrations are for pre-emergence use on crops including potatoes, cucurbits, cotton, corn and soybeans.

Work conducted in Tasmania over the past five years has shown that clomazone is very efficacious for control of certain emerged weeds in poppy (*Papaver somniferum*) crops. In many cases clomazone provides greater weed control with less crop damage than current commercial standard products. Clomazone used alone provides control of *Chenopodium album*, *Stachys arvensis* and *Polygonum aviculare*, with useful suppression of *Amaranthus powellii* and to a lesser extent *Raphanus raphanistrum*. In most commercial situations clomazone will be used in conjunction with other herbicides to provide control of all weeds present.

The ability to control emerged weeds with clomazone represents a significant breakthrough as the product has previously only been used pre-emergence. This is of particular benefit in poppies where the use of pre-emergence herbicides is not favoured.

INTRODUCTION

Approximately 10,000 ha of poppies (*Papaver somniferum*) are grown in Tasmania to supply raw materials to the pharmaceutical industry. Poppies are grown in rotation with temperate vegetable crops such as potatoes, peas and onions as well as brassica and cereal crops (mainly barley and wheat).

Market sizes for farm chemicals in minor crops such as poppies are small. There is little incentive for herbicide manufacturers to develop products for these minor markets and for the grower of poppies there is very limited information from other countries on the use of herbicides.

Common weeds found in most poppy crops include *Chenopodium album, Polygonum aviculare, Fumaria* spp., *Raphanus raphanistrum, Brassica rapa, Solanum nigrum* and *Capsella bursa-pastoris*. A number of others such as *Amaranthus powellii, Cirsium vulgare, Stachys arvensis, Stellaria media* and *Lamium amplexicaule* are important in some localities.

For over 15 years, weed control in Tasmanian poppies has been achieved using the following key strategy. At the four to six leaf stage of the crop, an overall application of ethofumesate + asulam is applied. This is followed three to six days later with a mixture of diquat and diclofop-methyl. In a number of paddocks this strategy is not adequate and one or more additional sprays are needed before and / or after the two key applications. These additional sprays may include use of the products already listed or other products including fluroxypyr, diflufenican or metosulam.

Germination and emergence of the small seeded poppy plant is often uneven. As poppies are very sensitive to variations in soil conditions and residual herbicides. Pre-emergence products are not favoured in this crop. Therefore, control of weeds needs to be through the use of post-emergence herbicides.

The two Tasmanian poppy contracting companies have invested in research to identify ways of improving weed control, reducing crop damage from herbicides and reducing the cost of weed control. Current practises are expensive and in many cases cause significant crop damage. The cost of herbicides used in Tasmanian poppies is often in excess of A$250 per ha or 10% of the gross value of the crop (Macleod, 1996).

MATERIALS AND METHODS

Over the past five years 24 replicated trials (randomised complete block, mostly four replicates) have been conducted in Tasmanian poppies to evaluate the performance of clomazone. In addition, a number of larger scale non replicated demonstration grower trials have been carried out. Small plots have been sprayed using flat fan jets applying 250 litres/ha at an application pressure of 280kPa. Plot sizes have ranged from 4 to 12 metres long by 2 metres wide. All assessments have been conducted as whole plot subjective ratings using the EWRS scales for weed efficacy (1 = total weed control, 9 = no effect on weeds) and crop tolerance (1 = no effect on crop, 9 = complete crop death). Clomazone (480 g/litre EC) has been compared to treatments containing ethofumesate (500 g/litre SC), asulam (400g/litre aqueous solution), diquat (200g/litre aqueous solution) and diclofop-methyl (375 g/litre EC).

RESULTS

Clomazone (240 g a.i./ha) applied at the cotyledon to 2 leaf crop stage provides good suppression of cotyledon to 2 leaf *Amaranthus powellii* (Table 1) with an average EWRS rating of 4.5. Increasing the rate of clomazone to (480 g a.i./ha) improved control as indicated by the lower rating of 3.4 (Table 1). This level of control is slightly less than the level of control offered by the standard treatment which rated 2.7.

Clomazone applied at the later timing provided slightly lower levels of *Amaranthus powellii* control than the early applications for the equivalent rates of product. The limited data presented indicate a rate response trend and greater control of smaller weeds when treatments are applied earlier.

Chenopodium album occurred in seven of the trials. Results show that clomazone at rates of 240 g a.i./ha and above controlled *Chenopodium album* (Table 2). The level of control achieved from a single application of clomazone was superior to that of the standard four herbicide treatment.

Table 1. Control of *Amaranthus powellii* using clomazone applied post-emergence in poppies

	Treatment Rates (g a.i./ha)			EWRS rating (no. of trials)
Crop Stage	C - 2 L	4 - 6 L	6 - 8 L	
Weed Stage	C - 2 L	C - 4 L	4 - 6 L	
	clomazone 120			6.0 (1)
	clomazone 240			4.5 (5)
	clomazone 480			3.4 (4)
		clomazone 240		5.8 (1)
		clomazone 480		4.4 (1)
		ethofumesate 500 + asulam 2000	diquat 200 + diclofop-methyl 750	2.7 (1)

Table 2. Control of *Chenopodium album* using clomazone applied post-emergence in poppies

	Treatment Rates (g a.i./ha)			EWRS rating (no. of trials)
Crop Stage	C - 2 L	4 - 6 L	6 - 8 L	
Weed Stage	C - 2 L	C - 4 L	4 - 6 L	
	clomazone 120			5.0 (1)
	clomazone 240			2.6 (7)
	clomazone 480			1.6 (4)
	clomazone 960			2.0 (1)
		clomazone 120		2.3 (1)
		clomazone 240		2.6 (2)
		ethofumesate 500 + asulam 2000	diquat 200 + diclofop-methyl 750	3.2 (6)

Six trials demonstrate the excellent activity of clomazone on *Polygonum aviculare* (Table 3). *Polygonum aviculare* is well controlled at rates as low as 120 g a.i./ha, applied between cotyledon and 4 leaf crop stage. The stage of the weeds controlled ranged from cotyledon to four leaf. The level of control offered by clomazone as a stand alone treatment was superior to that offered by the commercial standard.

Although limited data are presented for *Stachys arvensis,* this weed was controlled by all rates of clomazone tested (Table 4). Control of this weed with the current commercial products is limited with an EWRS score of 4.4 compared to clomazone scores ranging from 1.6 to 2.7. The two clomazone application timings investigated did not result in any difference in control of this weed.

Table 3. Control of *Polygonum aviculare* using clomazone applied post-emergence in poppies

	Treatment Rates (g a.i./ha)			EWRS rating (no. of trials)
Crop Stage	C - 2 L	4 - 6 L	6 - 8 L	
Weed Stage	C - 2 L	C - 4 L	4 - 6 L	
	clomazone 120			2.2 (3)
	clomazone 240			2.3 (6)
	clomazone 480			2.0 (5)
	clomazone 960			2.0 (1)
		clomazone 120		2.5 (1)
		clomazone 240		2.3 (1)
		clomazone 480		3.5 (2)
		ethofumesate 500 + asulam 2000	diquat 200 + diclofop-methyl 750	3.4 (2)

Table 4. Control of *Stachys arvensis* using clomazone applied post-emergence in poppies

	Treatment Rates (g a.i./ha)			EWRS rating (no. of trials)
Crop Stage	C - 2 L	4 - 6 L	6 - 8 L	
Weed Stage	C - 2 L	C - 4 L	4 - 6 L	
	clomazone 120			2.0 (1)
	clomazone 240			2.5 (2)
	clomazone 480			1.6 (2)
		clomazone 120		2.0 (1)
		clomazone 480		2.7 (1)
		ethofumesate 500 + asulam 2000	diquat 200 + diclofop-methyl 750	4.4 (2)

Raphanus raphanistrum is one of the more difficult weeds to control in poppy crops. Clomazone has provided suppression of this weed with many of the ratings similar to those of the commercial standard (Table 5). Increasing rate tended to increase control and the later application timing provided lesser control than that observed at the cotyledon to two leaf stage. As results are only available from one to three trials for this weed, cautious interpretation is needed.

In all trials crop tolerance to clomazone has been high (Table 6). Ratings have been similar for all rates tested and at both crop timings. This is in contrast to that generally observed for treatments containing ethofumesate and diquat which cause crop damage. This damage can lead to reduction in crop yield in some fields.

Table 5. Control of *Raphanus raphanistrum* using clomazone applied post-emergence in poppies

	Treatment Rates (g a.i./ha)			EWRS rating (no. of trials)
Crop Stage	C - 2 L	4 - 6 L	6 - 8 L	
Weed Stage	C - 2 L	C - 4 L	4 - 6 L	
	clomazone 120			4.8 (2)
	clomazone 240			4.2 (3)
	clomazone 480			3.7 (3)
	clomazone 960			4.0 (1)
		clomazone 480		6.0 (2)
		ethofumesate 500 + asulam 2000	diquat 200 + diclofop-methyl 750	4.5 (2)

Table 6. Tolerance of poppies to clomazone applied post-emergence

	Treatment Rates (g a.i./ha)			EWRS rating (no. of trials)
Crop Stage	C - 2 L	4 - 6 L	6 - 8 L	
	clomazone 120			1.8 (2)
	clomazone 240			1.5 (9)
	clomazone 480			2.2 (8)
	clomazone 960			2.3 (1)
		clomazone 120		1.5 (1)
		clomazone 240		1.8 (2)
		clomazone 480		2.0 (2)
		ethofumesate 500 + asulam 2000	diquat 200 + diclofop-methyl 750	3.4 (8)

DISCUSSION

Five years of small plot field trials have shown that clomazone at a rate of 240 g a.i./ha is an effective herbicide for broadleaf weed control in poppies. In particular, clomazone is highly efficacious on weeds such as *Chenopodium album* (Table 2), *Stachys arvensis* (Table 4), and *Polygonum aviculare* (Table 3), with useful suppression of *Amaranthus powellii* (Table 1) and to a lesser extent *Raphanus raphanistrum* (Table 5). The post-emergent use of clomazone represents a significant breakthrough as the product has previously only been used pre-emergence.

Clomazone exhibited excellent crop safety when applied to poppies from cotyledon to 4 leaf stage (Table 6). At the highest rate tested (960 g a.i./ha), applied at the cotyledon to 2 leaf stage, the level of crop injury was less than the commercial standard. This excellent crop safety of clomazone to poppies allows earlier application and consequently earlier weed control than that currently available. This is a significant improvement in the development of herbicide strategies for the poppy industry.

However, no single product can be expected to control all weeds in each poppy field and generally mixtures of two products and / or the use of more than one spray application is required in most fields. Extensive work has examined the efficacy and crop safety of clomazone when used in strategies with other poppy herbicides. Results show that clomazone can extend weed spectrum controlled with no reduction in crop safety. The use of clomazone tank mixes in multiple spray strategies with other poppy herbicides will be implemented commercially.

No detectable clomazone residues have been found in poppies. This assists in the registration of the product and allays concerns of customers of final poppy products.

Full registration of clomazone is anticipated for the coming season, its use commercially is expected to reduce the cost of weed control in most fields. In addition, it is possible that average crop yields may increase due to reduced crop damage from herbicides. On-going work may be needed to customise strategies for different weed spectra.

ACKNOWLEDGMENTS

This work has been funded by Tasmanian Alkaloids Pty. Ltd. The contribution of Dr Tony Fist and Phillip Mathews is gratefully acknowledged. Thanks also to FMC International Ag, producer of clomazone, for their invaluable support. Finally, the author thanks all Serve-Ag staff and in particular Matthew Sherriff who assisted with the preparation of the manuscript.

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POTENTIAL USE OF ALLELOPATHIC AGENTS AS NATURAL AGROCHEMICALS

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ABSTRACT

The indiscriminate use of herbicides has resulted in a) increasing incidence of resistance in weeds to some herbicide classes such as triazines and dinitro anilines b) shifts in weed population to species that are more closely related to the crop that they infest c) environmental pollution and potential health hazards. Allelopathy, an emerging branch of applied sciences which studies biochemical plant-plant and plant-microorganisms interactions, may help in overcoming such problems through development of crop varieties having greater ability to smother weeds, use of natural phytotoxins from plants or microbes as herbicides and use of synthetic derivatives of natural products as herbicides.

INTRODUCTION

Between 60 and 70% of the pesticides used in agriculture in developed countries are herbicides (Duke, 1997). Herbicides have helped farmers to increase yields while reducing labour. Without herbicides, labour would be a major cost of crop production in developed countries. However, the potential environmental and toxicological costs of herbicides have raised questions about our agricultural dependence on these magic solutions. In spite of modern control methods, even in developed countries that rely heavily on chemical herbicides for control, losses due to weeds, including efforts to control them plus losses in yield and quality, are relatively high.

Herbicides will continue to be a key component in most integrated weed management systems in the future. In the US, where herbicides dominate pesticides sales, a market herbicide sales of $4,000 millions is expected for the 2000 (Ainswoth,1996). Nevertheless, the indiscriminate use of herbicides has resulted in a) increasing incidence of resistance in weeds to some herbicide classes such as triazines and dinitro anilines b) shifts in weed population to species that are more closely related to the crop that they infest c) environmental pollution and potential health hazards.

At the present growth rate, the problem of evolved herbicide resistance will become a major concern of most farmers in developed countries in the near future. Herbicide resistance will also result in the use of methods for herbicides that will minimize the likelihood of the evolution of resistance, improving herbicide application technology to kill the weeds that are competing with the crop and by the use of highly potent herbicides with short-lived selection pressure, and of herbicides to which weeds apparently evolve resistance only very slowly. It is becoming increasingly important, to develop premixes of herbicides employing different modes of action, so you get both short-term efficacy and long-term control of a given weed spectrum.

Allelopathy (Molisch, 1969, Rice, 1984), an emerging branch of applied sciences which studies any process involving, mainly, secondary metabolites produced by plants, algae, bacteria, and fungi that influence the growth and development of agricultural and biological systems, including positive and negative effects (IAS, 1996), may help in overcoming such problems through development of crop varieties having greater ability to smother weeds, use of natural phytotoxins from plants or microbes as herbicides and use of synthetic derivatives of natural products as herbicides.

Plants have their own defence mechanisms and allelochemicals are, in fact, natural herbicides. One way to use allelopathy in agriculture is through the isolation, identification and synthesis of active compounds from allelopathic plant and microorganisms species. Keeping in mind this concept and with the notion that allelopathic compounds have a wide diversity of chemical skeletons, we present selected examples, belonging to modified ecosystems, selected sunflower cultivars, where they are involved as biocommunicators on allelopathy. Their potential use as natural herbicide templates is discussed in comparison with commercial herbicides.

MATERIALS AND METHODS

Seed germination bioassays: Seeds were obtained from FITÓ, S.A. The bioassay consisted of germinating 25 seeds for 5 days (3 for germination and 2 for root and shoot growth) of *L. sativa* L.vars. Nigra and Roman (lettuce), *L. esculentum* L.(tomato), and *A cepa* L. (onion); 25 seeds for 3 days of *L. sativum* L.(cress); 25 seeds for 7 days (4 for germination) of *D. carota* L. (carrot); 10 seeds for 5 days of *H. vulgare* L (barley), *T. aestivum* L.(wheat), *Z. mays* L.(maize) in the dark at 25°C into a Memmert ICE 700 growth chamber, in 9 cm plastic Petri dishes containing a 10 cm sheet of filter paper Whatman No.I and 5 ml of a test or control solution, except for maize (15 ml). Test solutions of pure compounds (10^{-4}M) and of commercial herbicides (10^{-2}M) were prepared as initial solutions.Test solutions (10^{-5}-10^{-9} M and 10^{-3}-10^{-6} M respectively) were obtained by diluting the stock solution. Parallel controls consisted of deionized water. Four replicates (100 seeds), except for barley, maize and wheat (20 replicates, 100 seeds), of each treatment, and parallel controls were prepared. All the pH values were adjusted to 6.0 before the bioassay using MES (2-[N-morpholino]ethanesulfonic acid, 10 mM).

Statistical treatment: The germination, root and shoot length values were tested by Welch's test being the differences between the experiment and the control, significant with a value of $P = 0.01$. The results are presented as figures 2 and 3, where units are expressed in % from the control, cero value means equal to control, every positive value means stimulation and any negative value means inhibition.

RESULTS AND DISCUSSION

The immediate applications of the knowledge of the structures and modes of action of allelopathic compounds are clear in terms of bio-rational herbicide development, design of agricultural strategies (crop rotation, tillage vs non tillage, use of cover crops, etc.) and soft environmental impact and has been widely commented by many authors (Rice, 1984, Einhellig, 1988, Macías, 1995).

Searching for new herbicide templates, we have developed in our laboratory a research project named "Natural Product Models as Allelochemicals" in which we are studying different plant species looking for compounds with phytotoxic activity. In continuation with our search for new agrochemicals based on their allelopathic properties we present 13 selected terpenoids: isolated from *Helianthus annuus* cultivars, eight belonging to the novel family of sesquiterpenes heliannuols (**1-8**) (Macías *et al.* 1994, Macías *et al.* 1997a), and five norsesquiterpenes (**9-13**) (Macías *et al.* 1997b) (Figure 1).

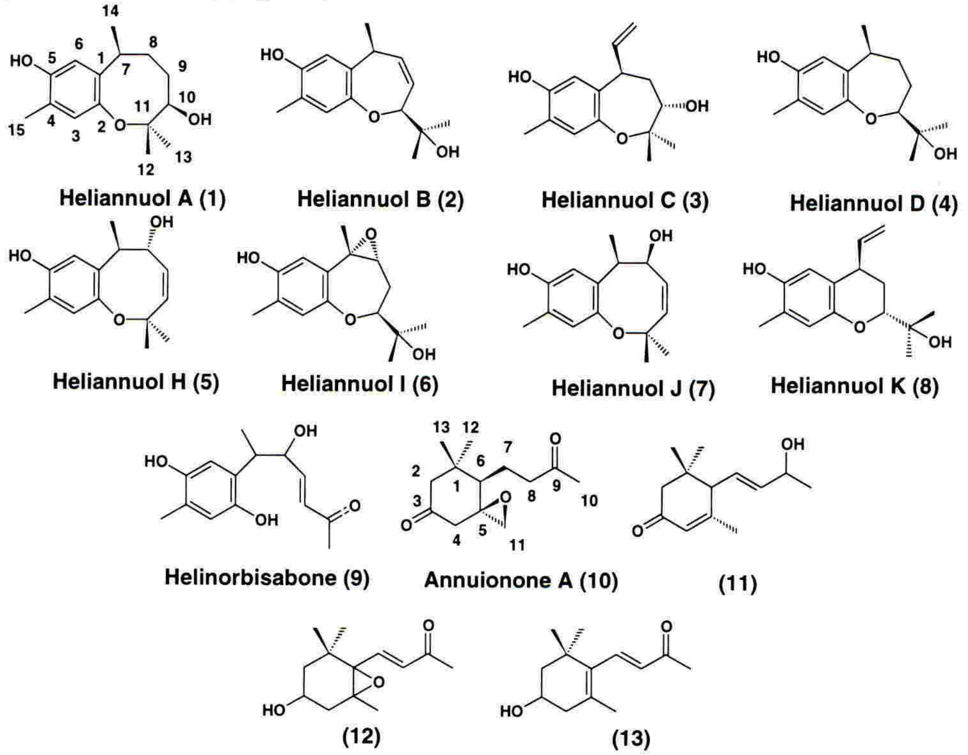

Figure 1.- Selected allelochemicals for comparison with commercial herbicides

In order to evaluate the potential of allelopathic agents as the basis of new herbicides, a number of bioassays have been undertaken with these agents in comparison to commercial herbicides used as internal standard.

To select the internal standard the following herbicides (that can be used alone or in mixtures, pre-, or post-emergence) provided for Novartis, simazine (as Gesatop 90 WP), terbutryn + triasulfuron (as Logran Extra), terbutryn + triasulfuron + chlorotluron (as Tricuran 64), terbutryn + chlorotoluron (as Dicurane Extra), terbutryn (as Igran Liquid), terbumeton + terbuthylazine (as Caragard), terbuthylazine + glyphosate (as Folar), simazine + amitrole (as Saminol 1089) and terbumeton + terbuthylazine + amitrole (as Vinagard) were tested (Figure 2). The range of test concentrations were 10^{-2}-10^{-9} M , based on the usual concentration applied on the field (10^{-2} M) and the range of activity shown by the allelopathic agents (10^{-4}-10^{-9} M). The standard target

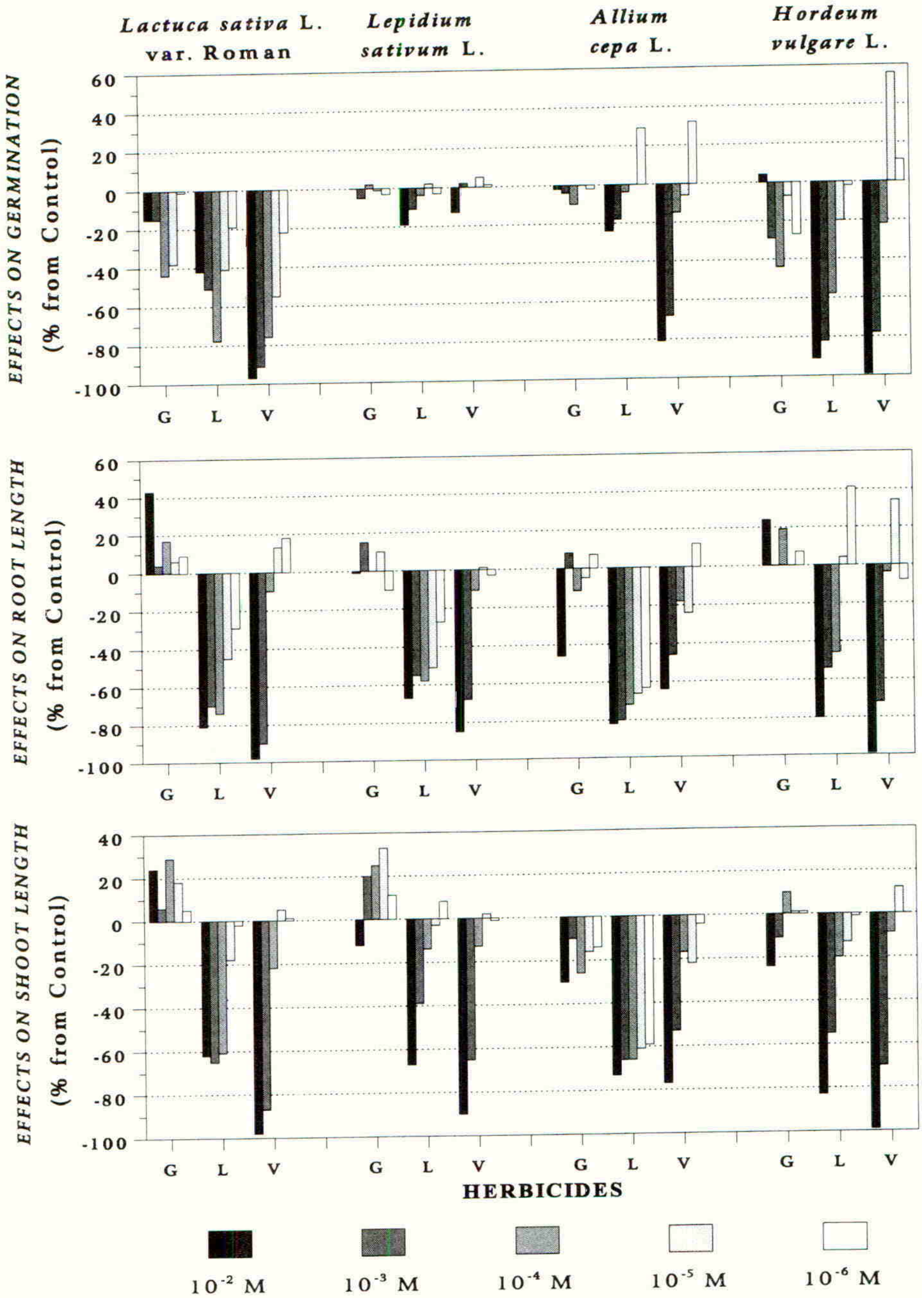

Figure 2.- Effects of selected commercial herbicides simazine (G, pre-emergence), terbutryn +triasulfuron (L, mix.) and terbumeton+terbuthylazine+amitrole (V, post-emergence) on the germination, radicle and shoot length of *L. sativa* L. var. Roman, *L. sativum* L., *Allium cepa* L. and *H. vulgare* L.

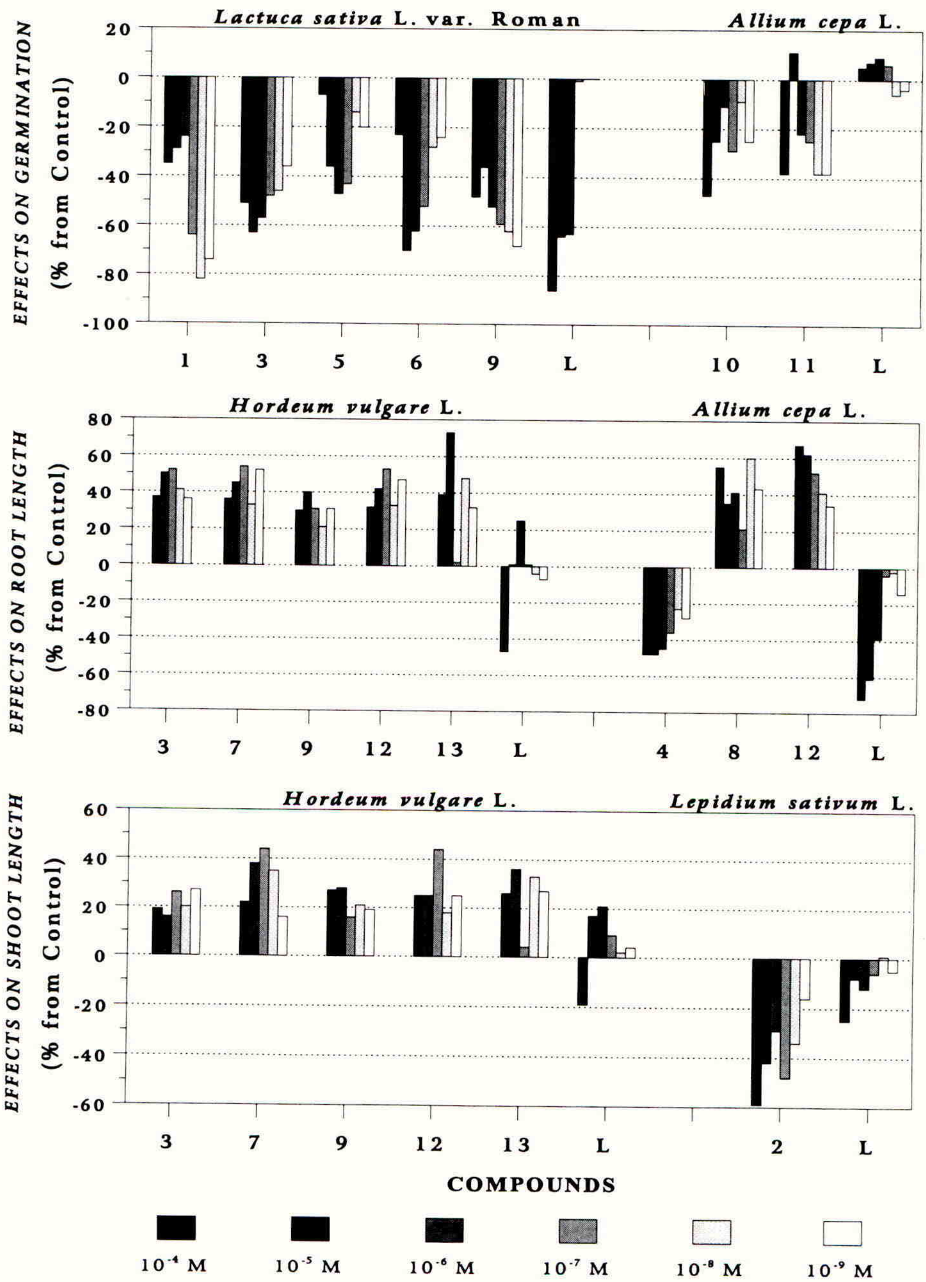

Figure 3.- Effects of selected allelopathic compounds 1-13 on the germination, radical and shoot length of *L. sativa* L. var. Roman, *L. sativum* L., *Allium cepa* L. and *H. vulgare* L. in comparison with the combination product terbutryn + triasulfuron (L, pre- and post- herbicide).

species were the dicotyledon species: *Lactuca sativa* L.vars. Nigra and Roman (lettuce), *Lycopersicum esculentum* L.(tomato), *Lepidium sativum* L.(cress), *Daucus carota* L. (carrot); and the monocotyledon species: *Allium cepa* L.(onion), *Hordeum vulgare* L. (barley), *Triticum aestivum* L.(wheat), *Zea mays* L.(maize), as representative of main dicotyledon weeds and important commercial crops.

It is interesting to notice that in general, in this standard phytotoxic allelopathic bioassay, herbicides shown strong inhibitory activities only at concentrations between 10^{-2}-10^{-3} M and at lower concentration this activity disappear or turn stimulatory (Figure 2). Based on the most consistent profile of activity of the nine test herbicides, which represent eight active principles in different formulations, the combination product terbutryn + triasulfuron (as Logran Extra) was selected to be used as an internal standard to validate the phytotoxic responses of the test chemicals.

Comparison of allelochemicals with the combination product terbutryn + triasulfuron (Figure 3) shows that, in general, allelochemicals have better profiles of activity in terms of concentrations and intensity. Thus, a strong inhibitory activity on germination and shoot length of dicotyledons, and stimulatory effects on root length of dicotyledons and root and shoot length of monocotyledons are observed, whilst the combination of herbicides is only active at high concentration on dicotyledons germination. Allelochemicals remains active even at concentrations as low as 10^{-9} M. They also show more sensitivity and selectivity against test parameters and species. These results can allow to propose new molecules as potential herbicide templates.

ACKNOWLEDGEMENTS

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LGC-40863: A NEW BROAD SPECTRUM POSTEMERGENCE HERBICIDE

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ABSTRACT

LGC-40863 is a new broad spectrum rice herbicide, developed as the first proprietary agrochemical product in Korea and currently being developed on an international basis by LG Chem. LGC-40863 has demonstrated excellent post-emergent activities against various grass and broadleaf weeds such as barnyardgrass, blackgrass and polygonums at the use rate of 30 g a.i./ha, while it was safe to rice as well as wheat and zoysiagrass at the same use rate.

LGC-40863 is an acetolactate synthase (ALS) inhibitor which offers low use rates and low mammalian toxicology profiles just like other ALS inhibiting herbicides. Environmental fate and toxicology studies indicate that LGC-40863 has an environmentally favorable profile. Low use rate combined with rapid soil degradation and less mobile properties in soil of LGC-40863 minimizes potential for leaching into ground water and/or accumulation in soil, allowing flexibility of crop rotation.

INTRODUCTION

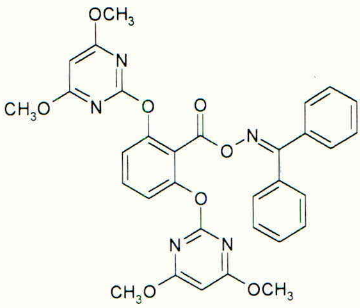
Since the invention of the first generation of acetolactate synthase(ALS) inhibiting herbicides such as sulfonylureas, imidazolinones and triazolopyrimidines (Brooks & Furmidge, 1990), great efforts have been made to discover new ALS inhibiting herbicides which offer unprecedented low use rates, low mammalian toxicology profiles and various crop selectivities. Recent introductions of Kumiai skeletons including KIH-2031 (Takahashi *et al*, 1991), KIH-6127 (Hanai *et al*,. 1993), KIH-2023 (Yokoyama *et al*, 1993) are successful stories in this field.

LGC-40863, a new ALS inhibiting herbicide, was discovered by researchers in the crop protection R&D group of LG Chemical in 1993 (Hur *et al*, 1995). In extensive glasshouse evaluations and field trials LGC-40863 proves to be effective for control of various grass and broadleaf weeds at low rates (below 60 g a.i./ha), while it shows high level of safety to rice, wheat, and zoysiagrass. After registration of LGC-40863 in Korea in 1997, LGC-40863 is currently under extensive field trials for the global marketing by LG Chemical with unnamed partners.

This paper summarizes physicochemical characteristics, ecological and toxicological profiles, environmental fate and biological performance of LGC-40863. The commercial development and registration of LGC-40863 in 1997 is the first successful case in Korea through long efforts to discover and develop proprietary pharmaceuticals and agrochemicals.

PHYSICAL AND CHEMICAL PROPERTIES

Structure:



Chemical name:	Benzophenone *O*-[2,6-bis-[(4,6-dimethoxy-2-pyrimidinyl)oxy] benzoyl]oxime (IUPAC)
Common name:	pyribenzoxim (ISO proposed)
Code name:	LGC-40863
Empirical formula:	$C_{32}H_{27}N_5O_8$
Molecular weight:	609.84
Melting point:	128-130°C
Physical state:	solid, white, odorless
Vapor pressure:	$<7.4 \times 10^{-6}$ torr
Octanol/water partition coefficient:	log P = 3.04
Water solubility:	3.5 ppm (at 25℃)

TOXICOLOGY AND ECOTOXICOLOGY (TECHNICAL MATERIAL)

Acute Oral LD_{50} (rat):	>5,000 mg/kg
Acute Oral LD_{50} (mouse):	>5,000 mg/kg
Acute Dermal LD_{50} (rat):	>2,000 mg/kg
Chromosome Aberration:	negative
Teratogenicity:	negative
Ames Test:	negative
Eye irritation:	non irritating
Skin sensitisation:	non irritating
96 hr LC_{50} (Madeka):	> 100 mg/L
48 hr LC_{50} (Daphnia):	> 100 mg/L
96 hr EC_{50} (Algae):	> 100 mg/L
24 hr LD_{50} (Honeybee):	> 100 mg/L

Studies so far indicate that LGC-40863 has highly favorable toxicological profile as other ALS inhibiting herbicide have.

ENVIRONMENTAL FATES

LGC-40863 was relatively immobile as observed by leaching test using artificial soil columns, showing more than 90% of LGC-40863 were accumulated between 0 and 10cm depth for either sandy loam soil or silty clay soil. LGC-40863 was not detected from the leachate. Organic carbon sorption coefficient (K_{oc}) was very high in four different soil types as shown in Table 1.

Furthermore, data collected from the field trial indicate that the half life of LGC-40863 in the field is only seven days. Based on the less mobile and rapid degradation properties of LGC-40863 leaching into ground water and/or accumulation in soil would not be a problem.

Table 1. Soil organic carbon adsorption constant of LGC-40863

soil type	pH	C.E.C(meq/100g)[1)]	Organic matter(%)	k_f[2)]	k_{oc}[3)]
sandy loam	4.3	3.7	1.7	8,820	5.19×10^5
silty clay	4.8	5.3	1.6	8,340	5.15×10^5
clay	5.9	16.6	2.5	2,100	8.57×10^4
silt loam	7.7	12.0	0.8	20,654	2.47×10^6

1) Cation exchangeable capacity
2) Freundlich soil adsorption coefficient
3) Soil organic carbon adsorption constant ($k_{oc}=k_f$/organic matter)

MODE OF ACTION AND SELECTIVITY

LGC-40863 inhibited ALS enzyme extracted from plants, having the I_{50} (herbicide concentration that inhibits ALS activity by 50%) values of 14 and 16 μM in rice and barnyardgrass, respectively (Bae *et al*, 1997). The herbicide also inhibited the whole plant ALS activity (*in vivo*) in both rice and barnyardgrass 24 h after treatment (Lim *et al*, 1997). These results indicate that mechanism of action of LGC-40863 is inhibition of ALS similar to other ALS-inhibiting herbicides. Little differences in I_{50} values between rice and barnyardgrass suggest that rice tolerance does not come from differential sensitivity at the target enzyme site. Further whole plant ALS assays showed that *in vivo* ALS activity recovered in rice within the 24 and 96 h period after treatment, but that this recovery did not occur in barnyardgrass (Lim *et al*, 1997). This result suggest that rice tolerance is based on a differential recovery mechanism due to the metabolic differences. Further metabolic studies are under investigation.

FORMULATION

At present, LGC-40863 is formulated as two different emulsifiable concentrates (1 and 10%

EC). One percent EC is currently being marketed in Korea. Dry formulations such as wettable powders and water dispersible granules are under investigation.

BIOLOGICAL PERFORMANCE

Weed spectrum and crop selectivity

The herbicidal activity has been evaluated mainly for rice in Korea, South East Asia and North and South America. In rice, optimum application rates for the post emergence application were between 30 to 50 g a.i./ha and it provided control of the weeds listed in Table 2.

Table 2. Weed spectrum of LGC-40863 in rice at 30 to 50 g a.i./ha (post application)

Good to complete (80 ~ 100%)	Moderate (50 ~ 80%)	Poor (<50%)
Echinochloa crusgalli	*Eleocharis kuroguwai*	*Cyperus serotinus*
Echinochloa colona	*Cyperus iria*	
Polygonum sp.	*Digitaria sanguinalis*	
Aneilema keisak		
Aeschynomene indica		
Bidens frondosa		
Sagittaria sp.		

LGC-40863 also controlled *Alopecurus* sp. in winter cereals and *Poa annua* in zoysiagrass at 30-60 g a.i./ha with potential crop tolerance as shown in Table 3. Potentials for those crops are under further evaluations.

Table 3. Herbicidal activity of LGC-40863 at 30 to 60 g a.i./ha (post application)

	Good (80 ~ 100%)	Moderate (50 ~ 80%)	Poor (<50%)
weed	*Alopecurus myosuroides* *Amaranthus retroflexus* *Galium aparine* *Poa annua* *Xanthium strumarium*	*Abutilon theophrasti* *Ipomoea nil* *Setaria viridis*	*Chenopodium album*
	Suscetible (60 ~ 100%)		Tolerant (<10%)
crop	*Glycine max* *Zea mays* *Gossipium hirsutum*		*Triticum aestivum* *Zoysia japonica*

Application window for *Echinochloa* control

LGC-40863 controlled *E. crusgalli* from the two-leaf to mature stage depending on rates as shown in Table 4 (Koo *et al,* 1997). This wide window will provide timing flexibility in application. .

Table 4. Barnyardgrass control of LGC-40863 at various growth stages[1].

application rate (g a.i./ha)	LS : leaf stage			
	2.5 LS	3.5 LS	5.5 LS	Tiller S
	(%)[2]			
60	100	100	100	100
30	100	100	95	95
20	95	85	70	60
10	95	85	40	20
5	90	80	20	5
2.5	90	60	0	0

1) Test was carried out in glasshouse.
2) Visual rating where 0 indicates no visible effect and 100 complete death of plants.

SUMMARY

LGC-40863 is a new postemergent rice herbicide. At 30 g a.i./ha rate LGC-40863 provides excellent control of barnyardgrass as well as various broadleaf weeds with a wide application windows. In preliminary field trials, LGC-40863 has also shown potential for weed control in wheat and zoysiagrass.

LGC-40863 inhibited ALS enzyme extracted from rice and barnyardgrass as well as whole plant (*in vivo*). Rice tolerance is considered as based on a differential recovery mechanism.
With the combination of low use rate, low toxicity, rapid soil degradation and no vertical movement into soil, LGC-40863 exhibits environmental favorable profile.

ACKNOWLEDGEMENT

We gratefully acknowledge and appreciate our colleagues and others who involved in whole process of the discovery and development of LGC-40863.

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JV 485: A NEW HERBICIDE FOR PRE-EMERGENCE BROAD SPECTRUM WEED CONTROL IN WINTER WHEAT

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ABSTRACT

JV 485 is a new selective herbicide discovered by Monsanto Company and jointly developed with Bayer AG. It is an inhibitor of protoporphyrinogen oxidase and results in the rapid onset of necrosis shortly after sensitive species emerge through the soil. Applied pre-emergence to winter wheat (*Triticum aestivum*) at rates of 125-175 g a.i./ha, JV 485 provides effective control of important grass weeds such as *Alopecurus myosuroides*, *Lolium* spp., *Apera spica-venti*, *Poa annua*, and *Phalaris* spp. as well as a large number of dicotyledonous weeds including *Galium aparine*. JV 485 has a favorable toxicological and environmental profile. It will provide suitable residual activity throughout the growing season, but does not pose a carryover risk to following crops.

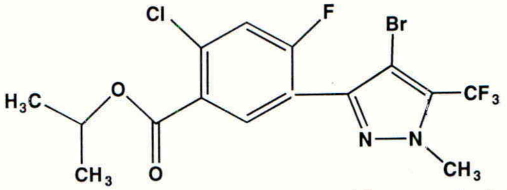
INTRODUCTION

Weed control strategies for European winter wheat often require multiple herbicide applications or combinations of products to achieve satisfactory results. The use of some active ingredients has raised environmental concerns relating to their leaching behavior leading to use restrictions for certain herbicides in some areas across Europe. Additionally, herbicide resistance has developed in recent years further complicating the best efforts of today's growers. New solutions are needed to address these challenges and allow growers to control economically important weeds effectively and to optimize yields.

JV 485 is a new pre-emergence wheat herbicide discovered by the Monsanto Company and jointly developed with the Agrochemical Division of Bayer AG. This novel chemistry provides broad spectrum control of many of the economically important weed species found in European wheat producing areas, including *Alopecurus myosuroides* and *Galium aparine*. Extensive testing across Europe during the last four years has shown that pre-emergence applications of 125-175 g a.i./ha can provide season-long weed control, including that of herbicide resistant *A. myosuroides* populations (Moss and Rooke 1997). These use rates are approximately 10x less than that of current broad spectrum products. While JV 485 does provide residual activity throughout the season, it will not have carryover restrictions relating to rotational crops following wheat. JV 485 exhibits a favorable environmental profile, thus movement of this active ingredient into groundwater or surface water supplies is very unlikely.

CHEMICAL AND PHYSICAL PROPERTIES

Structure:



Chemical Name (IUPAC):	5-[4-bromo-1-methyl-5-(trifluoromethyl)-1H-pyrazol-3- yl]- 2-chloro-4-fluoro-benzoic acid isopropyl ester
Common Name:	isopropazol (proposed)
Chemical Formula:	$C_{15}H_{12}BrClF_4N_2O_2$
Molecular Weight:	443.62 g/mole
Appearance:	fluffy, white crystalline solid
Melting Point:	79.5 - 80.5° C
Vapor Pressure @ 20° C:	9.43×10^{-6} Pa
Partition Coefficient: (octanol/water)	log Pow = 5.44
Water Solubility @ 20° C:	53 µg/litre
Hydrolysis:	stable at pH 4 and pH 5 4201 d at pH 7 (20°C) - calculated value 48.8 d at pH 9 (20°C)
Formulation:	JV 485 is formulated as a 500 g a.i./litre suspension concentrate

TOXICOLOGICAL AND ENVIRONMENTAL SAFETY

Acute toxicology

Acute Oral LD_{50} (rat):	>5000 mg/kg
Acute Dermal LD_{50} (rat):	>5000 mg/kg
Acute Inhalation LC_{50} (rat):	>1.7 mg/litre
Eye Irritation (rabbit):	slightly irritating
Skin Irritation (rabbit):	non-irritating
Skin Sensitization (guinea pig):	not a sensitizer

Genotoxicity

Ames Mutagenicity and HPRT/CHO:	negative
Micronucleus and in vitro cytogenetics:	negative

Environmental toxicity

Avian Oral LD_{50} (Bobwhite Quail and Mallard Duck):	>2130 mg/kg
Avian Dietary LC_{50} (Bobwhite Quail and Mallard Duck):	>5330 mg/kg

Earthworm LC_{50} (14 d):	>1170 mg a.i./kg dry wt soil
Rainbow Trout LC_{50} (96 h):	>0.045 mg a.i./litre*
Bluegill Sunfish LC_{50} (96 h):	>0.045 mg a.i./litre*
Daphnia EC_{50} (48 h):	>0.039 mg a.i./litre*

*values above the solubility limit

MODE OF ACTION

JV 485 is taken up by shoots of plants as they pass through the soil surface. Susceptible species quickly exhibit necrotic symptomology and die within days of emergence. The specific mode of action of JV 485 is through the inhibition of the mitochondrial and chloroplast enzyme protoporphyrinogen oxidase. The inhibition of this enzyme leads to an excessive formation of the singlet oxygen generating protoporphyrin IX (PPIX). In the presence of light PPIX produces singlet oxygen, which causes the rapid peroxidation of unsaturated membrane lipids and ultimately the destruction of plant cell membranes (Devine *et al.*, 1993). JV 485 can be classified Group E in the HRAC classification system.

FATE IN SOIL AND THE ENVIRONMENT

JV 485 shows a moderate to fast degradation in the soil through chemical and microbial means. The active ingredient was degraded under laboratory conditions (20°C) with one standard soil (Speyer 2.2) and three field soils with DT_{50} values ranging from 16-71 days (Table 1). Field dissipation studies in Europe confirmed the degradation rates measured under laboratory conditions.

Table 1. Aerobic degradation of JV 485 in laboratory studies using European soils

Soil Type (USDA Classification)	Soil Origin	pH (KCl)	Organic Carbon (%)	DT_{50} (d)
Clay Loam	Holms	5.1	1.94	40
Loam	Genoch	4.7	4.24	47
Silt Loam	Dupo	6.3	0.08	16
Loamy Sand (PH)	Speyer 2.2	5.8	2.40	71
Loamy Sand (PY)	Speyer 2.2	5.8	2.40	60

PH = radiolabel position in the phenyl ring, PY = radiolabel position in the pyrazole ring

Due to its very low water solubility (0.05 ppm) and strong adsorption/binding to soil constituents, JV 485 can be considered immobile (Table 2). Because of this it poses a minimal threat for movement down through the soil profile into groundwater or lateral movement into surface water. Lysimeter studies conducted over two consecutive years confirm this by showing concentrations of JV 485 in leachate samples to be well below 0.01 μg/litre.

Table 2. Adsorption/desorption laboratory studies

Soil Type (USDA)	Soil Origin	pH (KCl)	Organic Carbon (%)	Kd value (ml/g)	Koc value
Clay Loam	Holms	5.1	1.94	2.5×10^2	1.3×10^4
Loam	Genoch	4.7	4.24	2.9×10^2	0.7×10^4
Silt Loam	Dupo	6.3	0.08	1.4×10^2	1.7×10^4
Loamy Sand	Elder	5.8	1.30	2.0×10^2	1.6×10^4

Crop residue trials carried out according to GLP standards show no detectable residues of JV 485 in wheat straw or wheat grain at harvest.

FIELD TRIAL METHODS

During 1993-1997 JV 485 has been tested extensively in small plot efficacy and crop selectivity trials across Western Europe with particular emphasis on Germany, France, and the UK. The performance of JV 485 has been compared to relevant local standards, which most often included an early post-emergence treatment of isoproturon + diflufenican (IPU + DFF). All trials were fully randomized and contained a minimum of three replications. Plot dimensions were a minimum of 2 m x 6 m. Pre-emergence applications were made utilizing standard backpack spray equipment with application volumes of 200-250 litres/ha water. Visual observations were made for weed control (% biovolume reduction) and crop selectivity (% necrosis, stunting, and stand thinning). Late season weed control (May-June) is believed to be most relevant for assessing season-long performance and these values are reflected in the data presented. Crop selectivity assessments were made throughout the season with particular emphasis given to early season observations.

WEED CONTROL AND CROP SELECTIVITY

JV 485 applied at 125-175 g a.i./ha consistently provided season-long control of a broad spectrum of economically important weeds typically found in European winter wheat production. It performed well across many different soil types with only a slight decrease in efficacy on soils with high organic matter content. It effectively controls a large number of dicotyledonous weed species, including *G. aparine*, *Stellaria media*, *Matricaria chamomilla* and others (Table 3).

Table 3. Dicotyledonous weed species controlled with JV 485 pre-emergence at 125 g a.i./ha*

Aethusa cynapium	*Geranium* spp.	*Polygonum persicaria*
Anthemis arvensis	*Lamium* spp.	*Raphanus raphanistrum*
Aphanes arvensis	*Lapsana communis*	*Senecio vulgaris*
Arabidopsis thaliana	*Legousia speculum-veneris*	*Sonchus arvensis*
Capsella spp.	*Lithospermum arvense*	*Stellaria media*
Centaurea spp.	*Matricaria* spp.	*Veronica arvensis*
Cerastium vulgatum	*Mercurialis annua*	*Veronica persica*
Delphinium glaucum	*Myosotis arvensis*	*Vicia sativa*
Erodium circutarium	*Papaver rhoeas*	*Viola arvensis*
Galium aparine	*Polygonum aviculare*	*Viola tricolor*

*Data from multiple locations, control $\geq$93%

Particularly notable is the control of *G. aparine*, which due to its aggressive growth habit can be one of the most troublesome weeds in winter wheat (Table 4)

Table 4. Control of *Galium aparine* with JV 485 pre-emergence UK, Germany, France (1993/94, 1994/95, 1995/96)

Herbicide Treatment	Use Rate (g a.i./ha)	% control	No. of Results
JV 485	125	96.7	152
JV 485	175	99	81
IPU + DFF (post-em.)	1688	82.3	127

JV 485 provides good control of a variety of monocotyledonous weeds including two of the most widespread species in Western Europe, *A. myosuroides* and *Apera spica-venti* (Table 5). Additionally, JV 485 introduces a novel mode of action for the selective control of *A. myosuroides*, even as a number of biotypes have been identified with resistance to standard, commercial treatments. Independent testing shows no cross resistance to JV 485.

Table 5. Pre-emergence Activity of JV 485 on Important Monocotyledonous Weeds in Winter Wheat UK, Germany, France (1993/94, 1994/95, 1995/96)

	125 g a.i./ha	175 g a.i./ha
Alopecurus myosuroides	85 (250)	92 (161)
Apera spica-venti	95 (29)	99 (14)
Lolium multiflorum	85 (26)	92 (9)
Bromus sterilis	60 (14)	80 (13)
Poa annua	95 (24)	93 (13)
Phalaris paradoxa	92 (2)	-

*Percent control and number of trials

JV 485 is well tolerated by current winter wheat cultivars. Good selectivity has been shown at application rates up to 350 g a.i./ha.

ROTATIONAL CROPS

Because of its favorable dissipation pattern, JV 485 does not pose a carryover risk to normal rotational crops. As it is applied to the soil surface and remains there to provide effective control, any cultivation will further dilute remaining residues. No rotational restrictions are anticipated.

CONCLUSION

JV 485 offers a new, highly effective tool for the control of weeds in European winter wheat. It will provide season-long residual control with excellent crop safety, but due to a very good environmental profile will allow for rotational crop flexibility. JV 485 will be the low use rate option for broad spectrum control of many monocotyledonous and dicotyledonous weed species and will introduce a novel mode of action for the control of *Alopecurus myosuroides*.

ACKNOWLEDGEMENTS

The authors wish to acknowledge our many colleagues at Monsanto Company and the Plant Protection Division of Bayer AG for their contributions in bringing this project forward.

REFERENCES

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Moss S R; Rooke M S (1997) Activity of JV 485, a protoporphyrinogen oxidase inhibitor, on herbicide-resistant black-grass (*Alopecurus myosuroides*). *Proceedings of the Brighton Crop Protection Conference -Weeds.*

OXADIARGYL: A NOVEL HERBICIDE FOR RICE AND SUGARCANE

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ABSTRACT

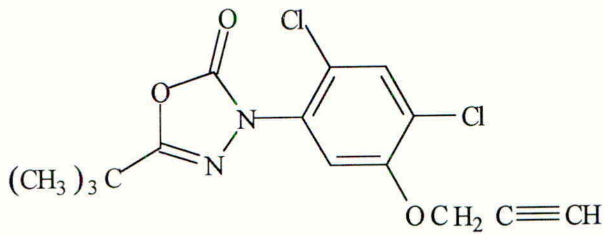
Oxadiargyl is a novel protoporphyrinogen IX oxidase herbicide discovered and developed by Rhône-Poulenc Agrochimie. It is active preemergence on both annual monocotyledons and dicotyledons as the product acts at germination as the new shoots come in contact with treated soil particles. Oxadiargyl is active via contact activity with very limited translocation following shoot uptake. Extensive development has been carried out in many countries for broadleaf weed, grass and annual sedge control in transplanted, dry direct seeded and water seeded rice. The effective dose rate (50 - 150 g a.i./ha), application timing and method are adapted to the different rice cultivation practices. Development is also on-going in sugarcane for pre-emergence weed control either on planted or ratoon cane. Good selectivity enables the use of a wide dose range depending on the desired persistence.

INTRODUCTION

The unfavourable environmental profiles of some residual herbicides has led to some limitations either in dose rates or in number of applications. Oxadiargyl is a novel pre-emergence herbicide discovered by Rhône-Poulenc Agrochimie and belonging to the oxadiazole chemistry group. Its toxicological, ecotoxicological and environment properties represent a significant advance in this area of chemistry. Its biological properties have been investigated in in-house evaluation farms for many years and by national crop protection organisations for registration purposes. Rice and sugarcane are the main targets for development followed by sunflower, transplanted vegetables and perennial crops.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name (IUPAC):	5-tert-butyl-3-(2,4-dichloro-5-propargyloxyphenyl)-1,3,4 oxadiazol-2-(3H)-one
Common name	Oxadiargyl
Code number	RP020630
Chemical family	Oxadiazoles
Molecular Formula	$C_{15}H_{14}O_3N_2Cl_2$
Structure	



Molecular weight	341.2
Appearance	Odourless and white powder with little agglomerates
Melting point	131°C
Aqueous solubility	0.37 mg/l at 20 °C

TOXICOLOGY (Technical material)

Acute Oral LD_{50} (rat)	> 5000 mg/kg
Acute Dermal LD_{50} (rat)	> 2000 mg/kg
Inhalation LC_{50} (rat 4 hours)	> 5.16 mg/l

Non-irritant to eye and skin
No skin sensitisation effect
Non-mutagenic

Sub-acute and chronic studies show that all species tested tolerate high levels of oxadiargyl for prolonged periods of time with few signs of toxicity. There is no specific issue concerning the mammalian toxicity

ECOTOXICITY (Technical material)

Aquatic

Tests have shown that the 96-hour LC_{50} of oxadiargyl on rainbow trout, bluegill sunfish and *Daphnia magnia* are below its water solubility.

Avian

Bobwhite Quail	Acute toxicity	LD_{50}:	> 2000	mg/kg
	Sub-Chronic Dietary toxicity	LC_{50}:	> 5200	ppm
		NOEL :	5200	ppm

ENVIRONMENTAL FATE

Oxadiargyl has been shown to be fairly rapidly degraded in four contrasting soil types with a mean DT_{50} of about 40 days. The two major metabolites are steadily degraded resulting in complete mineralisation to carbon dioxide and a soil bound residue. Oxadiargyl dissipates rapidly from the water to the sediment phase and is readily degraded under anaerobic conditions. It does not persist in the aquatic environment. Oxadiargyl and the two soil metabolites have been shown to have low mobility in four contrasting soil types and would not be expected to contaminate ground water.

MODE OF ACTION

Oxadiargyl is a selective herbicide active on weeds as a pre-emergence treatment. Effects begin at germination when the new shoots come into contact with oxadiargyl treated soil particles. Oxadiargyl inhibits protoprophyrinogen IX oxidase (Protox). There is no absorption of oxadiargyl in the plant and its efficacy does not depend on soil texture and type. The compound has shown limited activity by post-emergence application.

FIELD TRIALS IN RICE

Oxadiargyl has been tested on rice in different formulations: a suspension concentrate (SC 400 g a.i./l oxadiargyl), a water dispersible granule (WG 800 g a.i./kg oxadiargyl) and a wettable powder (WP 800 g a.i./kg oxadiargyl). These formulations have been applied by spraying or in mixture with sand or fertiliser before spreading in the paddy field. Emulsifiable concentrate formulations (30 and 60 g a.i./l oxadiargyl) have been developed for direct application via shaker bottle technology.

Transplanted rice

In transplanted rice, oxadiargyl is applied at low dose rates on 20 to 30 day old seedlings. Application on younger seedlings requires more attention; preliminary results indicate that post-transplanting application are safer provided that the crop has recovered from transplantation physiological stress.

Most of the development work has been done in the Asia / Pacific where transplanted rice still remains by far the major rice cultivation method. In China, oxadiargyl has been evaluated for registration and demonstration purposes. The applications have been made after transplanting either with a shaker bottle or after being mixed with sand or fertiliser. Trial results shown in Table 2, confirm that the application method has no significant impact on the activity of the molecule.

Table 1 : Weed control (%) in China 1994 - 95 - 96

	Oxadiargyl		Oxadiargyl + Sulfonylurea	Butachlor + Sulfonylurea	Reference (*)
Dose rate (g a.i./ha)	75	100	60-75 + 15-20	900 + 20	
Total weed control	85	89	90	82	86
Echinochloa crus galli	88	92	90	83	80
Commelina communis	65	76	-	58	58
Monochoria spp	89	91	88	94	83
Potamogeton distinctus	81	83	80	95	80
Rotala indica	95	98	-	91	100
Cyperus spp	91	92	90	95	93
Sagittaria pygmea	88	88	90	-	80
Sagittaria sagittifolia	95	91	97	100	91
Scirpus juncoides	66	79	70	75	88
Scirpus triqueter	81	88	-	-	83
Scirpus yagara	-	90	-	-	93
Scirpus spp	72	85	100	64	100

(*) The reference treatment is commonly a three way tank-mix with a grass killer, a broad-leaf killer and an herbicide effective against sedges.

Table 2 : Efficacy (% weed control) and selectivity (yield) of oxadiargyl at 100 g a.i./ha with different application technologies

	Fertiliser	Sand	Bottle
Total weed control	88	91	90
Echinochloa crus-galli	93	93	91
Broad-leaf weeds	88	89	92
Sedges	85	88	84
Yield (% untreated control)	126	114	117

In Pakistan in 1996, oxadiargyl 60 - 75 g/ha (EC 30 g a.i./l) gave excellent results on transplanted rice. Application was done with a knapsack sprayer three days after transplanting. Weed control was assessed 60 days after application. The mean of three trials is shown in table 3.

Table 3 : Weed control (%) in Pakistan 1996

	Oxadiargyl			Oxadiazon
Dose rate g a.i./ha	45	60	75	300
Cyperus rotundus	77	81	82	75
Cyperus iria	91	100	100	100
Cyperus difformis	87	92	100	91
Sphenoclea zeylandica	98	100	100	100
Nymphaea stellata	100	100	100	100
Marsilea minuta	100	100	100	100
Average yield kg/ha	1502	1553	1606	1518
Yield (% untreated control)	126	130	135	127

Yield in untreated control plot : 1191 kg/ha

Direct seeded rice

Early post-sowing application of oxadiargyl at 60 to 100 g/ha in pre-germinated rice ensures good control of annual grasses (*Echinochloa crus-galli*), annual Sedges (*Fimbristylis, Cyperus iria & C. difformis)* and broad-leaf weeds including *Rotala, Lindernia, Sphenoclea* species. In order to provide maximum crop safety it is better to recommend application on mud (and not in water) and to delay the first irrigation for 2 to 3 days .

Post-emergence application has to be made from the three leaf stage of the crop at approximately 200 g/ha oxadiargyl for the control of recently emerged weeds (up to cotyledon stage). In later applications (12 days after germination), oxadiargyl should be mixed with propanil (125 + 1000 g a.i./ha).

Red rice (*Oryza sativa*) is suppressed or controlled by an early pre-sowing (2 to 3 weeks before sowing) application of 100 to 300 g/ha of oxadiargyl. In case of very severe infestation, the application of a post-emergence herbicide (e.g. glyphosate) a few days before sowing will complement the efficacy of oxadiargyl. This weed control programme eases the sowing operations.

FIELD TRIALS IN SUGAR CANE

Applied pre-emergence, oxadiargyl (400 - 600 g/ha) provides effective control of annual grasses with good persistence, being particularly effective on *Leptochloa* spp and *Eleusine* spp. Some other major grasses are also well controlled : *Brachiaria* spp, *Digitaria* spp, *Echinochloa* spp, *Paspalum* spp. More troublesome species (*Rottboellia, Sorghum* and *Panicum*) are controlled with the higher dose rate and under favourable conditions: adequate soil moisture for germination and medium weed pressure.

Control of broad-leaf weeds is rather limited (*Amaranthus* spp, *Portulaca* spp, *Richardia* spp, *Solanum* spp) and a mixture of 400 - 600 g/ha oxadiargyl with 1250 - 1500 g/ha diuron or a triazine is needed in order to bring the control up to the levels of the standard treatments on *Acanthospermum*, *Bidens*, *Cleome*, *Commelina*, *Ipomoea*, *Indigofera*, *Ricinus* and *Oxalis*.

Oxadiargyl is selective for cane, both plant and ratoon. Specific variety trials carried out in Argentina have demonstrated that 800 g a.i./ha are selective for both. Soil type has no significant impact on efficacy and selectivity.

Table 4 : Weed spectrum of oxadiargyl in sugarcane - % Control 60 - 90 days after pre emergence applications

Dose rate g a.i./ha	500 - 600	800 - 900	1000 - 1200
Amaranthus deflexus	100	100	-
Amaranthus hybridus	80	90	95
Amaranthus viridis	85	90	-
Brachiaria decumbens	80	100	100
Brachiaria plantaginea	70	80	100
Cenchrus echinatus	40	70	90
Commelina virginica	50	70	80
Digitaria horizontalis	90	90	95
Echinochloa spp	80	80	90
Eleusine indica	90	95	100
Indigofera spp	70	90	100
Ipomoea spp	< 80	80	90
Leptochloa spp	90	90	-
Oxalis spp	-	80	-
Panicum maximum	80	85	100
Portulaca oleracea	90	95	-
Richardia brasiliensis	90	100	-
Rottboellia spp	50 - 80	80	80
Sida spp	75	85	90
Trianthema spp	-	80	90

CONCLUSION

Oxadiargyl, a new compound discovered by Rhône-Poulenc Agrochimie, has a very favourable toxicological, ecotoxicological and environmental profile. It is active by contact on emerging or recently emerged shoots with a residual effect related to applied dose rate.

Oxadiargyl controls a broad spectrum of weeds with pre-emergence or early post-emergence application and is selective for rice, sugarcane and other crops (sunflower, potato, transplanted vegetables and perennial crops).

In rice, the application is made post-transplanting as well as early post-sowing or post-emergence in direct seeded rice. Early pre-sowing application of oxadiargyl contributes to the control of red rice. Tank-mixes with various common rice herbicides have been successfully tested either for a broader weed control or for a wider application timing.
In plant or ratoon sugarcane, oxadiargyl controls the main weed species either by itself or in mixture with a triazine or diuron. The length of control is dose rate dependant.

ACKNOWLEDGEMENT

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AZAFENIDIN: A NEW LOW USE RATE HERBICIDE FOR WEED CONTROL IN PERENNIAL CROPS, INDUSTRIAL WEED CONTROL AND FORESTRY

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ABSTRACT

Azafenidin (DPX-R6447: 2-[2,4-dichloro-5-(2-propynyloxy)phenyl]-5,6,7,8-tetrahydro-1,2,4-triazolo[4,3-a]pyridin-3(2H)-one.), discovered by DuPont De Nemours Agricultural Products, is a new N-phenyl heterocycle herbicide which belongs to the subclass of the triazolones. The herbicide is formulated as a water dispersible, extruded paste granule, containing 80 % active ingredient. Azafenidin has a favourable environmental profile, with a relatively short half life, low environmental loading and large margins of safety to mammalian, avian, aquatic and other non target organisms.

In Europe, azafenidin will be primarily registered for weed control in vineyards, citrus and olive orchards, and for industrial weed control and forestry. Azafenidin can be applied safely to the ground under citrus and olive trees at any growth stage and in vineyards from the second year after planting. A rate of 240 gai/ha azafenidin can be applied alone pre-emergence to the weeds, or post-emergence in a tank mix with a contact or a post-emergence herbicide. These applications provide excellent control of many important species including grasses like *Setaria*, *Digitaria*, *Poa* and *Echinochloa* species, as well as broad leaf weeds such as *Amaranthus*, *Chenopodium*, *Malva*, *Brassica*, *Senecio*, *Solanum* and *Portulaca* species. The recommended rate offers 60 to 180 weed free days depending on weed species.

Azafenidin is an inhibitor of the porphyrin biosynthesis pathway. Weeds which have evolved resistance to this mode of action are extremely rare. Azafenidin is an excellent tool for herbicide resistance management in speciality crops.

INTRODUCTION

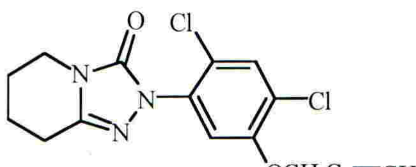
Azafenidin is a new N-phenyl heterocycle triazolone herbicide introduced by DuPont De Nemours, for the control of weed species in perennial crops, industrial weed control and forestry. In Europe, azafenidin will be primarly registered for weed control in vineyards (*Vitis sp.*), citrus (*Citrus sp.*) and olive (*Olea europaea*) orchards and secondly in forestry and industrial weed control. Further development is underway in several other crops: sugarcane, coffee, pineapple, etc. This novel active ingredient is a valuable tool for controlling a wide spectrum of weed species, such as *Setaria, Digitaria, Poa* and *Echinochloa* grasses, as well as *Amaranthus*, *Chenopodium*, *Malva*, *Brassica*, *Senecio* and *Portulaca* broad leaf weeds.

During the last decades, the extensive use of high rates of pre-emergence herbicides has resulted, in some instances, in the detection of some of these compounds in water (Pereira & Rostad, 1990, Price, 1991). At the same time, many economically important weeds developed tolerance to these standard herbicides (Heap, 1997, Powles & Holtum, 1994), which diminished their utility in various speciality crop markets. Several European governments reacted by either banning or severely restricting the use of these herbicides in speciality crops. The mode of action, the relatively low use rate and the soil fate of azafenidin offer a good tool for herbicide resistant weed management and an environmentally friendly alternative to speciality crop growers who want effective, long lasting control of their weeds, pre-emergence, or post-emergence in combination with a contact or a post-emergence herbicide.

Five years of field testing have confirmed the biological performances of azafenidin in Europe. A summary of the chemical and physical properties, the toxicological profile, the behaviour in the environment, the crop selectivity and the weed efficacy, outline the value of azafenidin.

CHEMICAL AND PHYSICAL PROPERTIES

DPX-R6447



Common name: azafenidin

Chemical name:

CAS: 2-[2,4-Dichloro-5-(2-propynyloxy)phenyl]-5,6,7,8-tetrahydro-1,2,4-triazolo[4,3-a]pyridin-3(2H)-one.

IUPAC: 2-[2,4-Dichloro-5-(prop-2-ynyloxy)-phenyl]-5,6,7,8-tetrahydro-2H-[1,2,4]triazolo[4,3-a] pyridin-3-one

Chemical formula: $C_{15} H_{13} N_3 0_2 Cl_2$

Molecular weight: 338.19 g/mole

Physical form:	white powdered solid
Melting point:	168-168.5 °C
Vapour pressure (at 20 °C):	1.0×10^{-11} Torr (1.3×10^{-9} Pa)
Dissociation constant (pK_a):	no indication of dissociation
Octanol/Water partition coefficient (at 20°C):	229

FORMULATION

Azafenidin is formulated as a water dispersible extruded paste granule (WG), containing 800 g/kg of the active substance. The product will be commercialised as Evolus® in Europe and Milestone® in the USA.

TOXICOLOGICAL AND ENVIRONMENTAL SAFETY

The toxicological and ecotoxicological studies completed thus far indicate that azafenidin presents a very low risk to humans, animals and the environment.

Acute tests for technical active ingredient

Acute oral toxicity	rats or mice:	LD_{50}>5000 mg/kg
Acute dermal toxicity	rabbits:	LD_{50}>2000 mg/kg
Acute inhalation toxicity	rats:	LC_{50}>5.3 mg/l (max. achievable concentration)
Acute skin irritation	rabbits:	Not a dermal irritant
Acute eye irritation	rabbits:	Not an ocular irritant
Dermal sensitisation	guinea pigs:	Not a skin sensitiser

Ames mutagenicity (*Salmonella typhimurium* and *Escherichia coli*): negative

Avian and aquatic organism tests for technical active ingredient

Avian oral toxicity	Bobwhite quail:	LD_{50}>2500 mg/kg	
	Mallard duck	LD_{50}>2500 mg/kg	
Dietary toxicity	Bobwhite quail:	LC_{50}>5620 mg/kg feed	
(5 days)	Mallard duck	LC_{50}>5620 mg/kg feed	
Aquatic fish toxicity	Rainbow trout	LC_{50}=33 mg/l	
(96 hours)	Blue gill sunfish	LC_{50}=48 mg/l	
Aquatic invertebrate	*Daphnia magna*	EC_{50}=38 mg/l	technical
toxicity (48 hours)		EC_{50}>300 mg/l	formulated
Algae toxicity	*Selenastrum c.*	EC_{50}=0.94 µg/l	technical
(120 hours)		EC_{50}=1.4 µg/l	formulated

A bioconcentration study in fish indicates that azafenidin will not bioaccumulate.

FATE IN THE ENVIRONMENT

Azafenidin degrades in soil *via* microbial degradation and photolysis. Hydrolysis is not important as a degradation mechanism. The rate of degradation has been evaluated under European field conditions on 4 sites. Results are summarised below.

Table 1. Characteristics of test soils (0-15 cm horizon)

Characteristic	Soil			
Location site	Spain Vilanuova de Castello	Southern France Cuxacd 'Aude	Italy Cerro Tanaro	Northern France Nambsheim
pH	7.5	7.5	6.1	7.5
Sand (%) 0-15 cm	11	12	6	21
Silt (%) 0-15 cm	46	67	72	58
Clay (%)0-15 cm	43	21	22	21
Texture[a]	clay loam	silty clay loam	silt loam	silt loam
Organic carbon (%)	1.14	1.34	1.02	1.41
Cation exchange capacity (mEq/100g soil)	15	12	13	15
Maximum water holding capacity, 0 bar (%)	41.9	36.6	42.3	44.6

[a] USDA/FAO soil classification system

Table 2. Summary of the rate of field degradation of azafenidin in Europe

DT mean values	Europe
DT50 [days][1]	25
DT90 [days][1]	168
DT50 [days][2]	40
DT90 [days][2]	133

[1] The decline times were calculated according to the best fitted curve described by Timme *et al*. (1986).
[2] The decline times were calculated by applying a kinetic model assuming a simple exponential decay.

Azafenidin is not expected to move and accumulate in soil. It binds well to soil. The mean K_{oc} in 4 soils is 298; there was minimal movement in soil column leaching studies using a very sandy soil and in the four field soil studies. Aged residues (i.e. azafenidin and its soil degradates) were demonstrated not to leach under worst case laboratory column leaching conditions and in the field. There is very low risk of azafenidin or its soil degradation products leaching to groundwater.

Azafenidin is expected to dissipate rapidly in natural waters. It is hydrolytically stable but photolyzes very rapidly in aquatic systems. Microbial degradation is very important.
The octanol/water partition coefficient of 229 suggests minimal risk of bioaccumulation

RESIDUES IN GRAPES, CITRUS AND OLIVE TREES

GLP tests carried out in France, Greece, Italy, Portugal and Spain showed no detectable residue of azafenidin (2 x 250 g a.i./ha) in all three crops.

MODE OF ACTION

Azafenidin is absorbed through the roots and shoots of susceptible plants and acts by inhibiting the porphyrin biosynthesis (PB) pathway. Specifically, azafenidin inhibits the activity of protoporphyrinogen oxidase (PROTOX).
Azafenidin is weakly xylem or phloem mobile; this explains the limited post emergence activity of the herbicide on well developed weed plants. However, azafenidin significantly improves the efficacy of post-emergence herbicides, such as glyphosate, and increases the speed of action of the contact products.

CROP SELECTIVITY

The selectivity of azafenidin on grape, citrus and olive cultivars is based upon the post directed placement of the herbicide onto the ground and the inability of the roots from the crops to absorb the herbicide. Azafenidin has been extensively tested on citrus, olive and grape cultivars at 240 (recommended rate), 480 and 960gai/ha. The selectivity of azafenidin has been evaluated on orange, lemon, tangerine and mandarin cultivars, from 1992 to 1997 in Spain, Italy and Greece, in 15 field trials. No crop injury symptoms have ever been detected on any of the cultivars at any stage of growth. The selectivity when used for young plants in nurseries is excellent.

The selectivity of azafenidin has been evaluated on 6 olive cultivars from 1992-1996 in Spain and Italy, in 4 field trials. No crop injury symptoms have ever been detected on any of the cultivars at any stage of growth. In addition, azafenidin has been applied, in severe conditions, on 4 month old olive plants, grown in pots, in comparison to the reference treatment: 3000g a.i./ha simazine. No significant differences of growth have been reported for the young trees treated with any rate of azafenidin, in comparison to the untreated plants, while those treated with a standard rate of simazine died.

The selectivity of azafenidin has been evaluated on 7 grape cultivars from 1993 to 1996, in France and Italy, in 11 field trials. Vineyards were at least 3 years old. No crop injury symptoms have ever been detected on any of the cultivars. Six complementary trials have been carried out from 1995 to 1997, in France, to evaluate the response of 14 grape cultivars planted in nurseries or in 1 or 2 year old non bearing fruit vineyards. At the recommended and the double rate, azafenidin was safe to all cultivars in all the trials, but one: in this test, the level of injury observed on a 1st year non-bearing fruit vineyard was marginal with 240 g a.i./ha azafenidin and unacceptable at 480 g a.i./ha, even though plant recovery was rapid and complete. Further field trials are currently being carried out to understand this issue. The introductory label of the product will recommend applying the herbicide on vineyards of at least 2 years of age.

WEED SPECTRUM OF HEBICIDAL ACTIVITY

For vineyards and citrus orchards, 240 g a.i./ha azafenidin can be applied once or twice per year from early spring to summer, according to weed emergence and the period required to maintain the field free of weeds. For olive orchards a single application of 240 g a.i./ha in autumn provides complete control, allowing the grower to harvest his crop effectively without interference from weeds.

The susceptibility of numerous weed species to 240 g a.i./ha azafenidin, applied pre-emergence, is summarised in table 3. The herbicidal activity of azafenidin has been evaluated in field trials carried out in France, Spain and Italy, from 1993 to 1996. The dates of application varied from March to June for vineyards, from April to July for citrus and from September to December for olive trees. Ratings have been performed 60 days after the application and averaged across the trials. A detail of the number of weed occurrences is given by country. The averaged level of weed response to the herbicide is provided, according to the following scale:

S Fully susceptible (85-100% control),
MS Moderately susceptible (75-84 %)
MT Moderately tolerant (50-74 %)
T Tolerant (0-49 %)

<u>Control of *Convolvulus arvensis*</u>

The control of *Convolvulus arvensis* can be achieved by an early post-emergence application of 240 g ai/ha azafenidin plus 0.1 % v/v Trend 90® surfactant (90 % KG691), followed by a later application at the same rate.

The first application should be made on young *Convolvulus arvensis* plants (1 to 2 leaf stage) and repeated after weed regrowth or a new flush.

Certain annual weeds have more than one flush of seedling emergence. To maximise the control of such weeds it may be necessary to use 2 sequential applications of azafenidin, straight or in tank mix with a post-emergence herbicide at 60-90 days interval.

Table 3. Weed control spectrum of azafenidin tested in grapes, citrus and olive orchards

Weed species	Test per country Italy	France	Spain	Test Total	Response
Broad leaf weeds:					
Amaranthus albus		6	6	12	S
Amaranthus blitoides			15	15	S
Amaranthus retroflexus	19	16	30	65	S
Amaranthus viridis			15	15	S
Anagallis arvensis		5	4	9	S
Beta maritima			3	3	S
Calendula arvensis	1		9	10	S
Capsella bursa-pastoris		3		3	S
Chenopodium album	2	14	15	31	S
Chrysentemum spp.			4	4	S
Coronopus squamatus		3		3	S
Diplotaxis erucoides		1	19	20	S
Epilobium tetragonum		12		12	MS
Erodium cicutarium		3		3	S
Euphorbia prostrata			15	15	S
Fumaria spp.	1		12	13	(MS)-S
Geranium spp.	1	5		6	S
Heliotropium europaeum			4	4	S
Lactuca scariola		4		4	S
Lamium spp.	2	4	8	14	S
Malva sylvestris			16	16	S
Polygonum spp.	3	15	2	20	S
Portulaca oleracea	10	4	32	46	S
Raphanus raphanistrum		1	1	2	S
Reseda phyteuma			4	4	S
Rumex acetosella		2		2	MS
Rumex crispus		2		2	T
Rumex obtusifolius	1	1		2	S
Senecio vulgaris	2	10		12	S
Sinapis arvensis & alba	9	1	5	15	S
Solanum nigrum	1		2	3	S
Sonchus asper	1	6		7	S
Stellaria media	11	2	11	24	S
Veronica spp.	6	7		13	S
Urtica urens	1		2	3	S
Grasses:					
Agrostis stolonifera		3		3	S
Alopecurus mysuroides	4			4	S
Bromus spp.			3	3	S
Cynodon dactylon	4	2		6	T
Digitaria sanguinalis		17	4	21	S
Echinochloa spp.	1	12	5	18	S
Lolium rigidum	7		3	10	S
Poa annua	3	5	4	12	S
Poa trivialis		4		4	S
Setaria spp.	14	3	15	32	S
Sedges:					
Cyperus rotundus	2		14	16	T
Others:					
Allium vineale		4		4	S

CONCLUSION

Azafenidin is a new N-phenyl heterocycle triazolone herbicide for broad spectrum weed control in speciality crops. Toxicological and environmental data indicate a low risk of toxicity to humans and animals, a low risk of bioaccumulation, no accumulation in the soil, a low risk of leaching in water and no crop residues.

The potent pre-emergence activity of azafenidin on numerous annual and several perennial weed species makes of azafenidin a building block for long lasting weed control in grape vineyards, citrus and olive orchards. Its compatibility with post-emergence herbicides, such as glyphosate, is an excellent tool for extending the period free of weeds from 1 to 3 months, therefore reducing the number of applications and trips to the field.

Very rare instances of weed resistance to PBI herbicides have been discovered in the last 30 years (Heap, 1997, Powles & Holtum, 1994). Therefore, azafenidin is a valuable tool to develop strategies for controlling weeds, which have evolved tolerance to herbicides with different modes of action. For instance, several resistant biotypes to triazines, aryloxyphenoxypropionates ("Fops"), cyclohexanediones ("Dims") and acetolactate synthase (ALS) herbicides are efficiently controlled by 240 gai/ha azafenidin.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the efforts of all our DuPont colleagues who contributed to the discovery, the development and registration of azafenidin, and in correcting this manuscript.

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BAY YRC 2388: A NOVEL HERBICIDE FOR CONTROL OF GRASSES AND SOME MAJOR SPECIES OF SEDGES AND BROADLEAF WEEDS IN RICE

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ABSTRACT

BAY YRC 2388 (Fentrazamide, proposed common name) is a new tetrazolinone herbicide being developed on an international basis within the Bayer organization. BAY YRC 2388, a cell division inhibitor, provides excellent efficacy against barnyardgrass and annual sedges with a wide and flexible application timing, from pre-emergence up to 3 leaf stage of the targeted weeds. Due to excellent rice compatibility, even on young rice seedlings, and long residual activity, BAY YRC 2388 is ideally suited for simultaneous application with the transplanting operation, thereby saving the cost and time necessary for a separate herbicide application. Combinations with sulfonylureas for broadleaf weed control offer herbicide products that cover the entire weed spectrum in transplanted rice in Japan.

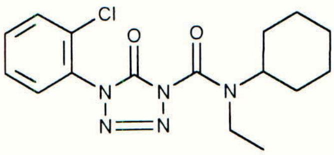
INTRODUCTION

Barnyardgrass (*Echinochloa* spp.) is the most common and troublesome weed in paddy rice cultivation in Asia. The weed is spread about 90% of the whole rice growing area in Japan (1). Such a wide distribution of the weed results in severe yield and quality losses (2). The efficient weed control by herbicides having high efficacy against dominant paddy weeds and good compatibility to rice is one of the most important objectives for practical rice cultivation. BAY YRC 2388 has an excellent efficacy against barnyardgrass within a wide range of growth stages from pre-emergence up to 3 leaf stage of the weed with good compatibility to rice. Biological performance of BAY YRC 2388, and applicability of some formulations of mixtures with sulfonylureas, such as bensulfuron-methyl, imazosulfuron and cyclosulfamuron were investigated under field conditions to develop new types of rice herbicides.

The mixtures provide excellent efficacy against a wide variety of economically relevant weed species in transplanted rice.

CHEMICAL & PHYSICAL PROPERTIES

Chemical Structure:



Chemical Name: 4-(2-chlorophenyl)-5-oxo-4,5-dihydro-tetrazole-1-carboxylic acid cyclohexyl-ethyl-amide (IUPAC)

Common Name: fentrazamide (ISO proposed)

Code Name: BAY YRC 2388 (international)
NBA 061 (for official tests in Japan)

CAS Reg. No.: 158237-07-1

Chemical Formula: $C_{16}H_{20}ClN_5O_2$

Molecular weight: 349.82 g/mole

Appearance: Colorless Crystals

Melting Point: 79 °C

Dissociation Constant: Does not dissociate

Vapor Pressure: 5×10^{-10} hPa (20 °C)

Solubility:

Water	=	2.3	mg/litre at 20 °C
2-Propanol	=	32	g/litre at 20 °C
Xylene	=	> 250	g/litre at 20 °C

Partition Coefficient: log Pow = 4.01

Henry Law Constant 7×10^{-6} Pa x m^3/mole

TOXICOLOGY & ECOBIOLOGY OF TECHNICAL MATERIAL

Acute Toxicity:	Oral LD_{50} Rat	>5,000 mg/kg
	Dermal LD_{50} Rat	>5,000 mg/kg
	Inhalation LC_{50} Rat	>5,000 mg/m^3
Irritation	Eye Rabbit	Non-irritating
	Dermal Rabbit	Non-irritating
Skin Sensitization	Guinea pig	Not sensitizing
Mutagenicity	Ames Test	Non-mutagenic
	Cyt. in vitro	Non-mutagenic
Teratogenicity:	Rabbit & Rat	Non-teratogenic
Fish Toxicity	LC_{50} Carp	3.2 mg/l (48h)
	LC_{50} Rainbow trout	3.4 mg/l (48h)
Water Flea Toxicity	LC_{50} *Daphnia magna*	>10 mg/l (3h)

Beneficial Insect Toxicity	Silkworm	NOEC	100 ppm
	Honeybee	LD_0	> 150 µg/bee (topical)

ENVIRONMENTAL FATE

Hydrolysis:	pH 5 (25 °C)	DT_{50} >300 days
	pH 7 (25 °C)	DT_{50} >500 days
	pH 9 (25 °C)	DT_{50} ca.70 days
Photolysis:	Pure Water (25 °C)	DT_{50} ca.20 days
	Natural Water (25 °C)	DT_{50} ca.10 days
Soil Metabolism: (under paddy condition)	Volcanic soil	DT_{50} ca.30 days
	Alluvial soil	DT_{50} ca.20 days
Soil Mobility:	Japanese paddy soil	Koc =500~3400

MODE OF ACTION

The mode of action of BAY YRC 2388 at the molecular level has not yet been identified. But morphological studies revealed effects indicating a similarity in mode of action to oxyacetamide herbicides like mefenacet. Complete arrest of cell division in the root and shoot meristemic regions result in halted growth and distortion of elongated tissue. Accordingly, BAY YRC 2388 can be classified in group K 3 (cell growth inhibitors) by the HRAC classification system.

HERBICIDAL PROPERTIES OF BAY YRC 2388

Weed control efficacy and plant compatibility of BAY YRC 2388 under practical field conditions are shown in Table 1. BAY YRC 2388 as 2 and 3% GR at 10 kg/ha (200 and 300 g a.i./ha) is highly effective against barnyardgrass (*Echinochloa* spp.), one of the most troublesome weeds in paddy rice with good compatibility to transplanted rice at applications from 0-DAT (0 Days After Transplanting, i.e. simultaneous application with transplanting of young rice seedlings, before emergence of weed) up to 3 leaf stage of the weed. The herbicide is also effective against *Cyperus difformis*, *Monochoria vaginalis* and *Eleocharis acicularis*. The efficacy against weed species such as *Scirpus juncoides*, *Sagittaria pygmaea* and *Cyperus serotinus*, and some species of broad leaved annual weeds, is sometimes insufficient.

Table 1. Weed control efficacy and plant compatibility of BAY YRC 2388 (10 trials)

Appli. time***	Efficacy* ECHSS	CYPDI	SCPJU	MOOVP	BBBBB	ELOAL	SAGPY	CYPSE	Phy-tox** ORYSP
BAY YRC 2388 2% GR 10kg prep./ha									
0-DAT	100	100	50	95	85	100	20	30	3
0-1 LS	100	100	40	95	80	100	20	20	3
1-2 LS	97	100	30	90	70	100	10	10	0
BAY YRC 2388 3% GR 10 kg prep./ha									
1-2 LS	100	100	30	90	80	100	10	10	3
2-3 LS	97	100	20	80	60	100	0	0	0

* Efficacy: percentage of weed control; >90: practically acceptable

** Phyto-toxicity: percentage of damage; <10: practically acceptable

*** Appli. time: leaf stage of ECHOR. 0DAT: pre-em. appli. at the time of transplanting

ECHSS: Barnyardgrass (*Echinochloa oryzicola*, *E. crus-galli* var *crus-galli* and *E. formosensis*)

CYPDI: *Cyperus difformis*, SCPJU: *Scirpus juncoides*, MOOVP: *Monochoria vaginalis*, BBBBB: annual broadleaved weeds. ELOAL: *Eleocharis acicularis*, SAGPY: *Sagittaria pygmaea*, CYPSE: *Cyperus serotinus*, ORYSP: *Oryza sativa*, (rice transplanted)

COMBINATIONS WITH SULFONYLUREAS

Some mixtures of BAY YRC 2388 with sulfonylurea herbicides are also under development to extend weed control spectrum against major species of sedges and broadleaved weeds under various rice growing conditions. Special easy-to-use formulation types e.g. SC and floating granules (GF, internal abbreviation), as well as 0-DAT and toss type application techniques have been addressed in particular in order to meet the farmer's demand for labor saving in practical rice cultivation. Weed control efficacy and plant compatibility of the mixtures are indicated in Table 2 and can be summarized as follows.

BAY YRC 2388 & cyclosulfamuron & dymron GR and
BAY YRC 2388 & bensulfuron-methyl SC:
BAY YRC 2388 & cyclosulfamuron & dymron 2.0 & 0.6 & 4.0% GR and BAY YRC 2388 & bensulfuron methyl 4.0 & 1.5% SC at the rates of 10 kg prep./ha (200 + 60 + 400 g ai/ha) resp. 5 L prep./ha (200 + 75 g ai/ha) are highly effective against all tested weeds with good selectivity in transplanted rice at 0-DAT application. Simultaneous application of herbicides with the transplanting operation of young rice seedlings by special applicators attached to transplanters is one of the new and promising techniques for effective labor saving. Herbicidal properties of these two BAY YRC 2388 mixtures are ideally suitable for this new technique.

BAY YRC 2388 & imazosulfuron & dymron GR:
BAY YRC 2388 & imazosulfuron & dymron 3.0 & 0.9 & 10.0% GR at the rate of 10 kg prep./ha (300 + 90 + 1,000 g ai/ha) is effective against all tested weeds with good plant compatibility to transplanted rice at application at 2~3 leaf stage of barnyardgrass. Broadcasting of GR formulation of herbicides into paddy fields after transplanting of rice seedlings is the most common method of herbicide application in Japan. Thus, this mixture fits in the conventional application techniques.

BAY YRC 2388 & bensulfuron-methyl GF (floating granule):
GF is a new type of formulation of rice herbicides for easy-to-use application. Floatable granules are packed in a water soluble bag to be thrown into paddy fields under flooding conditions. BAY YRC 2388 & bensulfuron methyl 7.5 & 1.27% GF, packed at 40 grams per bag, at the rate of 4 kg prep./ha (300 + 51g ai/ha) is highly effective against all tested weeds with good plant compatibility to transplanted rice at application at the 2 leaf stage of barnyardgrass.

Table 2. Weed control efficacy and plant compatibility of some BAY YRC 2388 mixtures

Appli. time	Efficacy ECHSS	CYPDI	SCPJU	MOOVP	BBBBB	ELOAL	SAGPY	CYPSE	Phy-tox ORYSP
BAY YRC 2388 & cyclosulfamuron & dymron 2.0 & 0.6 & 4.0% GR 10 kg prep./ha									
0-DAT	100	100	100	100	100	100	95	100	3
BAY YRC 2388 & bensulfuron-methyl 4.0 & 1.5% SC 5 L prep./ha									
0-DAT	100	100	100	100	100	100	97	96	0
BAY YRC 2388 & imazosulfuron & dymron 3.0 & 0.9 & 10.0% GR 10 kg prep./ha									
2 - 3 LS	100	100	100	100	100	100	100	100	0
BAY YRC 2388 & bensulfuron-methyl 7.5 & 1.27% GF 4 kg prep./ha									
2 LS	100	100	100	100	100	100	97	95	3

CONCLUSIONS

In conclusion, the attributes of BAY YRC 2388 can be summarized as follows:

- Stable efficacy against barnyardgrass and other dominant weeds in paddy
- Season long residual control
- Wide application window from 0-DAT up to 3 leaf stage of ECHSS
- Good crop compatibility to rice even at transplanting
- Favourable toxicological, environmental and ecobiological properties
- Favourable properties as a mixing partner of sulfonylureas
- Suitable for modern formulation types

ACKNOWLEDGMENT

All data contained herein have been generated and compiled within the organizations of Nihon Bayer Agrochem K.K. in Japan and Bayer AG in Germany. We, the authors, would like to express our gratitude to our colleagues of the two organizations, and to acknowledge their efforts in this project for the development of BAY YRC 2388.

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MY-100, A NEW HERBICIDE FOR PRE- AND EARLY POST-EMERGENCE BARNYARD GRASS CONTROL IN RICE

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ABSTRACT

MY-100, 3-[1-(3,5-dichlorophenyl)-1-methylethyl]-2,3-dihydro-6-methyl-5-phenyl-4*H*-1,3-oxazin-4-one is a new oxazinone herbicide discovered by Rhône-Poulenc Yuka Agro K.K. MY-100, a novel type of cell growth inhibitor, has provided excellent activity on *Echinochloa* spp., sedges and certain broad-leaved weeds in paddy rice at the rate of 30 g a.i./ha when applied pre-emergence. Extensive field trials in 1993 - 1996 in Japan have shown that MY-100 + sulfonylurea herbicide mixtures as a one-shot herbicide provides excellent selective control of both annual and perennial weeds when applied pre- to early post- emergence in transplanted rice. In the field, MY-100 provides season long residual activity with no carry over effects into following crops such as wheat, barley, chinese cabbage, radish and onion have been confirmed through 3 years of successive application. A number of field trials have shown possibilities for the application of MY-100 to direct seeded rice in Japan. To date all toxicological and environmental studies of MY-100 show favorable results.

INTRODUCTION

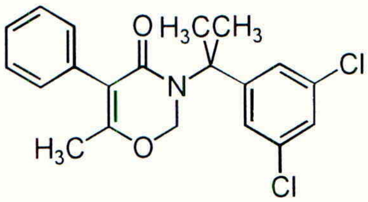
Echinochloa spp. is one of the most important weeds in paddy rice field in the world. It is one of the most competitive weeds in rice. Its seed-setting and germination percentage is so high that its control is very difficult. Infestation of *Echinochloa* spp. causes severe yield loss and quality reduction in rice cultivation. Therefore, rice growers are looking forward to the introduction of a new herbicide that has long residual activity and wide application window for control of *Echinochloa* spp.

MY-100 is a new herbicide discovered by Rhône-Poulenc Yuka Agro K.K. This compound shows excellent efficacy on *Echinochloa* spp., sedges and certain broad-leaved weeds in paddy fields and excellent selectivity on transplanted rice when applied pre- to early post-emergence.

Since 1992, many field trials of MY-100 and its combination with some sulfonylurea herbicides have been conducted in transplanted rice and a number of field trials of MY-100 have been conducted in water seeded rice in Japan. This paper reports the herbicidal activities of MY-100 as a rice herbicide.

CHEMICAL AND PHYSICAL PROPERTIES

Structure:



Chemical Name (IUPAC):	3-[1-(3,5-dichlorophenyl)-1-methylethyl]-2,3-dihydro-6-methyl-5-phenyl-4*H*-1,3-oxazin-4-one
Common Name:	oxaziclomefone (ISO proposed)
CAS Reg. No.:	[153197-14-9]
Empirical Formula:	$C_{20}H_{19}Cl_2NO_2$
Molecular Weight:	376.28
Appearance:	white crystal
Melting Point:	149.5~150.5 °C
Water solubility:	0.18 ppm at 25 °C
Vapor Pressure:	$\leq 1.33 \times 10^{-2}$ m Pa at 50 °C
Hydrolysis:	T 1/2 = 30~60 days at 50 °C
Partition Coefficient: (Octanol/Water)	log Kow = 4.01

TOXICOLOGY (Technical Material)

Acute Oral LD_{50} (rat, mouse):		> 5000 mg/kg
Acute Dermal LD_{50} (rat, mouse):		> 2000 mg/kg
Eye Irritation (rabbit):		Minimal irritant
Skin Irritation (rabbit):		Non-irritant
Skin Sensitization (guinea pig):		Non-sensitization
Ames Mutagenicity:		Negative
Teratogenicity (rat, rabbit):		Non-teratogenic
Fish Toxicity :	Carp 48-hr LC_{50}	> 5 ppm

FORMULATION

MY-100 is available as granules (GR), a suspension concentrate (SC), a wettable powder (WP) and water dispersible granules (WDG). The product is available as extruded calcium carbonate granules for granule application. Jumbo granule formulations are under development.

MODE OF ACTION

The target site of MY-100 has not yet been identified. It inhibits meristem growth in a manner dissimilar from any known herbicides. Biochemical investigations have shown partial reversal by gibberellic acid indicating cell wall biosynthesis as a likely target. Further investigations are ongoing. As MY-100 is applied post-emergence in flooded paddies, it is taken up mainly by roots and shoots. The initial symptoms of MY-100 on *Echinochloa* spp. are observed in the new leaves, followed by chlorosis, reddish coloration of leaves and shoots (anthocyanin formation), necrosis and plant death. Under normal conditions, sensitive rice weeds are killed within 1-2 weeks of treatment, depending on their growth stage at application and also on weather conditions.

HERBICIDAL ACTIVITY

Weed Control Spectrum

Pre-emergence

MY-100 has provided excellent control of *Echinochloa oryzicola*, *Cyperus difformis*, *Rotala indica*, *Elatine triandra* and *Eleocharis acicularis* at 20 g a.i./ha, *Monochoria vaginalis* and *Lindernia procumbens* at 40 g a.i./ha, *Scirpus hotarui* at 80 g a.i./ha and *Cyperus serotinus* at 160 g a.i./ha. However, MY-100 at even 320 g a.i./ha have shown poor efficacy on *Sagittaria pygmaea* with pre-emergence application (Table 1).

Table 1. Herbicidal activity of MY-100 against main paddy weeds applied pre-emergence.

Weeds	Herbicidal Activity				
Rate (g a.i./ha)	20	40	80	160	320
Echinochloa oryzicola	100	100	100	100	100
Cyperus difformis	100	100	100	100	100
Monochoria vaginalis	60	90	100	100	100
Rotala indica	90	95	100	100	100
Lindernia procumbens	70	90	100	100	100
Elatine triandra	90	95	100	100	100
Eleocharis acicularis	100	100	100	100	100
Scirpus hotarui	40	80	98	98	98
Sagittaria pygmaea	0	0	0	0	10
Cyperus serotinus	0	30	80	100	100

Herbicidal activity was evaluated visually by 0 to 100 scale : 0 = no effect 100 = complete kill

Post-emergence

MY-100 has provided excellent control of *Eleocharis acicularis* at 20 g a.i./ha, *Echinochloa oryzicola*, *Cyperus difformis*, *Rotala indica* and *Elatine triandra* at 40 g a.i./ha, *Lindernia procumbens* at 80 g a.i./ha and *Monochoria vaginalis* at 160 g a.i./ha. However, MY-100 at even 320 g a.i./ha has shown poor efficacy on *Scirpus hotarui*, *Sagittaria pygmaea* and *Cyperus serotinus* with post-emergence application (Table 2).

Table 2. Herbicidal activity of MY-100 against main paddy weeds applied post-emergence (2.5 leaf stage of *Echinochloa oryzicola*).

Weeds	Herbicidal Activity				
Rate (g a.i./ha)	20	40	80	160	320
Echinochloa oryzicola	80	100	100	100	100
Cyperus difformis	80	90	95	100	100
Monochoria vaginalis	50	50	50	90	90
Rotala indica	80	90	100	100	100
Lindernia procumbens	60	80	90	90	90
Elatine triandra	80	90	100	100	100
Eleocharis acicularis	90	95	100	100	100
Scirpus hotarui	0	20	20	50	60
Sagittaria pygmaea	0	0	0	0	0
Cyperus serotinus	0	60	60	60	80

Herbicidal activity was evaluated visually by 0 to 100 scale : 0 = no effect 100 = complete kill

APPLICATION WINDOW

MY-100 at rates of 30 - 60 g a.i./ha provided excellent control pre-emergence to *Echinochloa oryzicola* up to the 3 leaf stage (Table 3).

Table 3. Efficacy of MY-100 on different growth stages of *Echinochloa oryzicola* in glasshouse trials.

Compound	Rate (g a.i./ha)	Herbicidal Activity				
		Pre-emergence	1 leaf stage	2 leaf stage	2.5 leaf stage	3 leaf stage
MY-100	60	100	100	100	100	100
	30	100	100	100	100	80
	15	100	100	70	60	40

Herbicidal activity was evaluated visually by 0 to 100 scale : 0 = no effect 100 = complete kill

RESIDUAL ACTIVITY

MY-100 provided excellent control of *Echinochloa oryzicola* for 50 days after treatment. The residual activity of MY-100 at the rate of 60 g a.i./ha was superior to mefenacet at the rate of 1200 g a.i./ha under flooded condition in the glasshouse (Figure 1).

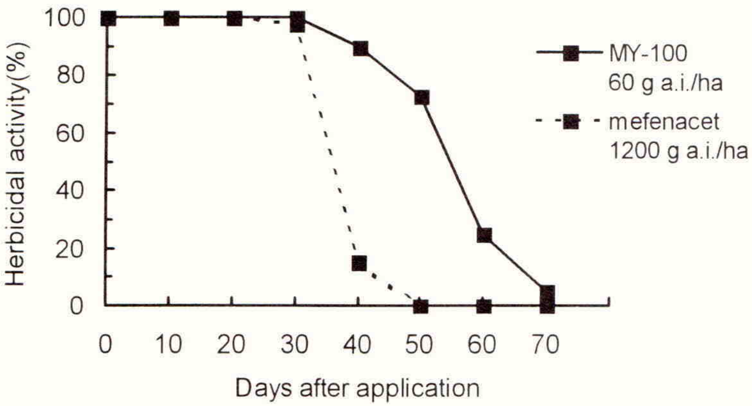


Figure 1. Residual activity of MY-100 on *Echinochloa oryzicola*.

CROP SELECTIVITY

The selectivity of MY-100 to transplanted rice is mainly based upon physical selectivity, not biological selectivity. After treatment with MY-100, under flooded conditions, a herbicide-treated layer is formed. The soil sorption constant of MY-100 is very high and leaching is very low (< 1 cm). Consequently, MY-100 does not reach the rice roots (planted depth ≥ 1 cm) and shows high selectivity in transplanted rice.

Phytotoxicity of MY-100 to 2 leaf stage of rice (different transplanted depth) under flooded condition were investigated in the glasshouse. MY-100 at rates of 60-120 g a.i./ha caused sever phytotoxicity to 0 cm transplanted rice. However, these treatments provided high selectivity on 1-3 cm transplanted rice, being superior to mefenacet (Figure 2).

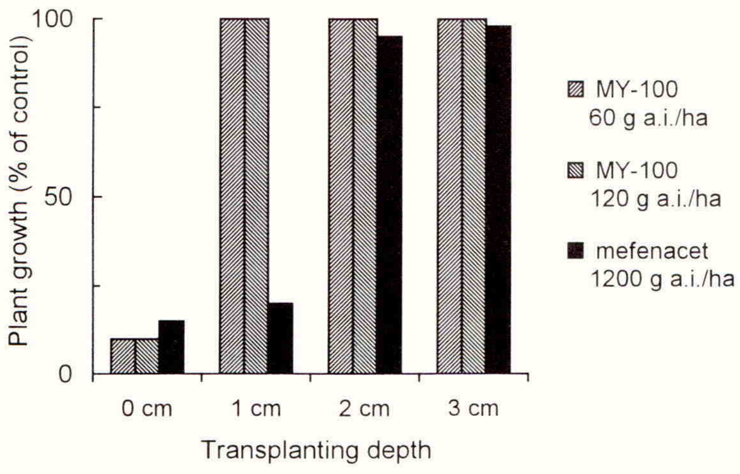


Figure 2. Crop safety of MY-100 on transplanted rice (*Oryza sativa*, cv Koshihikari).

FIELD TRIALS

Transplanted Rice

During 1993 to 1996, efficacy and selectivity trials have been conducted by The Japan Association for Advancement of Phyto-Regulators (JAPR). The performance of MY-100 applied in mixtures with sulfonylurea herbicides has been tested as one-shot herbicides on transplanted rice in Japan. MY-100 mixtures with sulfonylurea herbicides and/or other herbicides have provided excellent efficacy on the main paddy weeds and excellent selectivity on transplanted rice with both pre- and post-emergence application (2.5 leaf stage of *Echinochloa* spp.) (Table 4 and 5).

Table 4. Herbicidal activity and selectivity of MY-100 + sulfonylurea herbicide mixtures on main paddy weeds and rice applied pre-emergence by JAPR in 1996.

Weed or Crop species	% control (No. of tests)		
	MY-100 + bensulfuron-methyl + azimsulfuron	MY-100 + imazosulfuron + dymron	MY-100 + pyrazosulfuron-ethyl
Formulation	GR	SC	WDG
Rate (g a.i./ha)	80+30+6	60+85+900	60+21
Echinochloa oryzicola	100.0 (10)	100.0 (10)	100.0 (10)
Cyperus difformis	100.0 (8)	98.8 (8)	100.0 (6)
Monochoria vaginalis	99.8 (9)	99.8 (8)	98.0 (8)
Lindernia procumbens	99.8 (10)	98.0 (10)	98.8 (10)
Scirpus hotarui	98.8 (10)	99.9 (10)	99.2 (10)
Sagittaria pygmaea	99.3 (9)	97.9 (8)	96.0 (8)
Cyperus serotinus	100.0 (8)	100.0 (9)	97.5 (7)
Oryza sativa	1.1 (10)	0.0 (10)	1.0 (10)

Table 5. Herbicidal activity and selectivity of MY-100 + sulfonylurea herbicide mixtures on main paddy weeds and rice applied post-emergence by JAPR in 1996.

Weed or Crop species	% control (No. of tests)		
	MY-100 + bensulfuron-methyl + azimsulfuron	MY-100 + imazosulfuron + dymron	MY-100 + pyrazosulfuron-ethyl
Formulation	GR	SC	WDG
Rate (g a.i./ha)	80+30+6	60+85+900	60+21
Echinochloa oryzicola	98.5 (10)	99.1 (10)	99.1 (10)
Cyperus difformis	100.0 (8)	100.0 (8)	100.0 (6)
Monochoria vaginalis	100.0 (9)	99.6 (8)	98.6 (8)
Lindernia procumbens	99.8 (10)	98.3 (10)	96.5 (10)
Scirpus hotarui	97.8 (10)	99.5 (10)	96.0 (10)
Sagittaria pygmaea	97.6 (9)	97.4 (8)	92.8 (8)
Cyperus serotinus	97.6 (8)	99.8 (9)	92.8 (7)
Oryza sativa	0.0 (10)	1.0 (10)	1.0 (10)

Water Seeded Rice

In 1992, efficacy and selectivity trials were conducted in Japan. The performance of MY-100 applied alone was compared with a standard reference treatment (molinate at 4,000 g a.i./ha). At the one leaf stage of *Echinochloa oryzicola*, MY-100 provided excellent efficacy at the rate of 25-100 g a.i./ha being similar to molinate. However, the efficacy on 3 leaf stage of *Echinochloa oryzicola* was inferior to molinate even at the rate of 100 g a.i./ha (Figure 3).
On the 1 leaf stage of rice, MY-100 provided excellent to good selectivity at the rate of 25-50 g a.i./ha. However at the rate of 75-100 g a.i./ha it showed severe phytotoxicity. On the 2 leaf stage of rice, MY-100 provided excellent selectivity at the rate of 25-50 g a.i./ha, similar to molinate with marginal selectivity at the rate of 75-100 g a.i./ha (Figure 4).

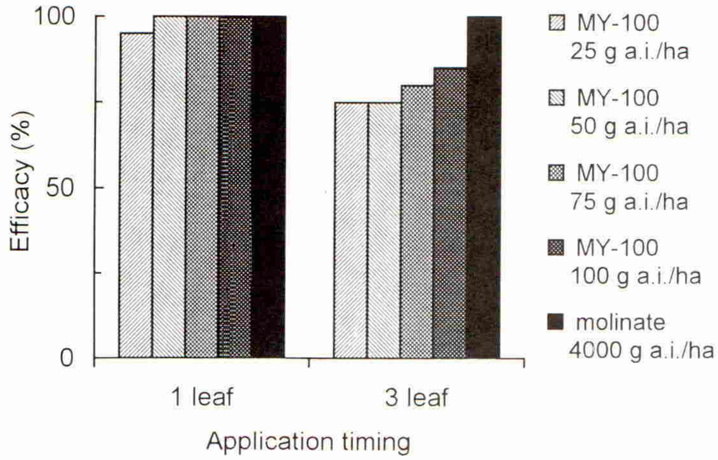


Figure 3. Efficacy of MY-100 against *Echinochloa oryzicola*.

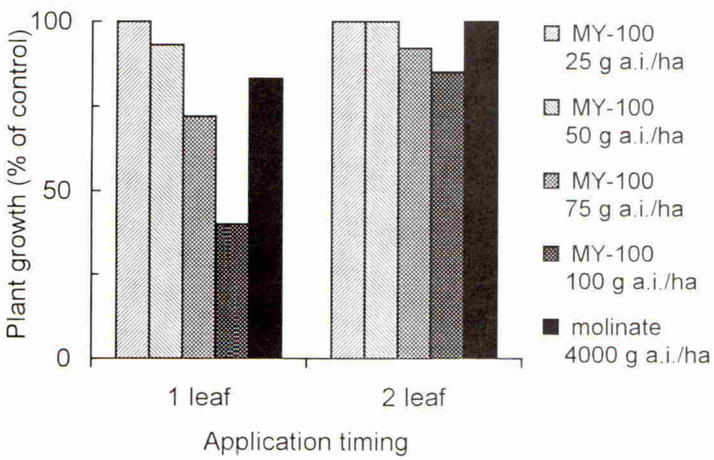


Figure 4. Crop safety of MY-100 on water-seeded rice (*Oryza sativa*, cv Koshihikari).

CARRY OVER

From 1994 to 1996 carry over trials were conducted. MY-100 have been applied successively for 3 years at the rate of 80 - 320 g a.i./ha. After rice harvest, following crops were grown according to customary cultivation methods and the biomass and yields were investigated. MY-100 has shown no carry over effects in following crops such as wheat, barley, chinese cabbage, radish and onion (Table 6).

Table 6. Effect on following crops through 3 years successive application of MY-100.

Crops	Fresh Weight (% of control)				
	MY-100				mefenacet
Rate (g a.i./ha)	80	160	240	320	1200
Winter wheat	96.3 a	119.8 a	93.4 a	100.1 a	114.6 a
Winter barley	103.9 a	135.3 a	114.4 a	110.3 a	114.1 a
Chinese cabbage	96.4 a	118.3 a	99.5 a	104.5 a	100.5 a
Radish	101.6 a	119.2 a	103.2 a	113.6 a	83.9 a
Onion	93.1 a	99.6 a	102.6 a	107.1 a	100.0 a

Means followed by same letter do not significantly differ (P=0.05, Duncan's MRT)

CONCLUSION

In conclusion, the attributes of MY-100 can be summarized as follows:

1. New mode of action for control of *Echinochloa* spp.

2. Very low application rates such as 30 - 80 g a.i./ha in transplanted rice and 25 - 50 g a.i./ha in water seeded rice.

3. Wide application window from pre-emergence to 2.5 leaf stage of *Echinochloa* spp. for transplanted rice in paddy fields.

4. Season long residual activity in one application for the control of *Echinochloa* spp.

5. Very low carry over risk.

6. Very favorable toxicological and environmental properties.