SESSION 1

THE THIRTEENTH BAWDEN LECTURE

CHAIRMAN	MR R. F. NORMAN
SPEAKER	MR J. J. NORTH
SESSION ORGANISER	DR K. J. BRENT

USE AND MANAGEMENT OF THE LAND: CURRENT AND FUTURE TRENDS

J. J. NORTH

Department of Land Economy, University of Cambridge

INTRODUCTION

The subject chosen by the Programme Committee is most appropriate and timely. The current wide ranging debates on future land use must with some urgency reach conclusions, to enable the important policy, strategy and investment decisions to be made, not just within the UK or the EEC, but worldwide.

Forecasting trends is always hazardous, particularly when one recognises that patterns of land use will be influenced by a multitude of factors including changes in the economic situation within and outside agriculture, institutional factors specific to agriculture and also elsewhere, technical changes in farming, food processing and manufacture, environmental policies relating to the use of the countryside, international policies and trading agreements. In the EEC as a whole there is concern regarding the overproduction of food and associated budgetary costs, the impact of modern farming on the environment, the problems associated with falling farm incomes and the need to maintain viability in rural areas. Long term decisions are required as priorities and investment in R & D must have long time horizons whilst agricultural production is also long term when compared to most other industries, major shifts involve adjustments over several years.

As 77% of the land area in the UK and 63% of the land area in the EEC (10 countries) is devoted to farming and since the list above does indicate the importance of agricultural considerations in land use policies, perhaps the views of an agriculturalist would advance the debate at least in some sectors. Even so, within a very short time I would expect legitimate criticisms of my views presented here.

In this lecture I am attempting to look at recent trends in agriculture and associated problems, at developments in technology which will provide options for future changes, and finally at the outcome as I see it and its influence on crop protection. I shall consider mainly the situation in the EEC and draw examples from the UK in particular, but this will necessitate considerable reference also to world-wide trends. Land 'use' in this context is simply the purpose to which the land is put e.g. crop production, forestry, recreation, wildlife conservation, whereas 'management' refers to the technology applied to achieve this purpose.

SUPPLY AND DEMAND

As recently as the early 1970s there were serious shortfalls in food production in relation to world demand and at the end of 1973 there were virtually no reserve stocks of food available. Forecasts made just six years ago, of future demand based on population and income growth, predicted a continuation of demand exceeding supplies and forecasted a future world scarcity of food (e.g. 'Global 2000'). Land budgets for the UK for the year 2000 foresaw the need to protect agricultural land from other uses to maintain a reasonable level of self sufficiency for the remainder of the century (Edwards & Wibberley 1971, Centre for Agricultural Strategy 1976). Primacy of food production for land and other resources appeared to be the requirement world wide.

The food supply and demand situation had changed dramatically by only 1982 (Table 1). In part due to a fall in demand arising from the world economic recession and the inability of many countries to purchase imports of food; and in part due to a succession of very large harvests around the world, supplies substantially exceeded demand and large stocks rapidly built up, mainly in the United States and in the EEC. There is every prospect that this supply/demand imbalance will pertain into the future as the continuing application of technology will increase the world's food production potential.

TABLE 1 World Grain Consumption and Stocks (million tonnes)

	1964	1974	1984
Consumption	1000	1250	1500
Stocks	150	137	210
Stocks as % of Consumption	15%	11%	14%

In 1985 USA grain stocks were 230 million tonnes and EEC stocks 17 million tonnes at the end of the season. Grain stocks in the EEC were not considered excessive representing only around 8 to 9 weeks consumption; stocks of skim milk powder (900 000 tonnes), butter (1.3 million tonnes) and beef (700 000 tonnes) were regarded as excessive.

The FAO report 'Agriculture: Towards 2000' predicted surpluses of grain in the developed world in excess of deficiences in the developing world of some 48 million tonnes, and also surplus sugar, vegetable oil and protein seeds from the developing world. World food production has increased by approximately 2% per annum over the past 10 years, but excluding China world output per capita has declined by 0.2% annually. Per capita food production has declined in 50% of the 111 countries reporting, including 29 countries in Africa, over the past 10 years (USDA 1986).

Food needs can only be converted into demand by surplus income becoming available to purchase food and this will be slow as population growth is largely concentrated in developing and centrally planned countries. In the recent past the USSR and China have both purchased large quantities of food on the world market, and their success or otherwise in increasing their self sufficiences will have a substantial impact on future world trade and export opportunities.

ATTITUDES AND ECONOMICS

In the EEC and particularly in the UK, the contemporary struggles between competing alternatives for the use of land have entered a new phase, with the apparent prospects of secure and adequate food supplies and current production levels giving rise to surpluses. An increasingly mobile population and the British desire for open space, creates pressures for greater access to the countryside for recreational purposes. The surplus food situation and the ever increasing costs of the Common Agriculture Policy, have given more weight to the arguments to protect and enhance landscape features, and wildlife habitats and to increase the biological diversity in the countryside, by changes in agricultural policy and farming methods. It is the more intensive use of the land for food production which is the major source of criticism, because intensification reflects a reduction of wildlife habitats, landscape and access, increased use of chemicals, reduction in areas of land not in food production and a general loss of biological diversity. By its very nature, this criticism implies that some greater control is needed over the use made of the land and also the management systems being practised. Public attitudes to land use are becoming an increasingly important influence.

In many European countries there is strong support for measures which reduce inputs into farm production, such as fuel and energy, fertilisers, pesticides and purchased animal feeds. This is from a number of standpoints. Reducing inputs produces lower outputs and hence supplies; reduced inputs lead to lower intensity of land use and decrease the opportunities for specialisation whilst sustaining the current farm structure and employment levels and encouraging mixed farming. Environmentally and socially this approach has many advantages, but in addition to the difficulties of administering these arrangements, the consumer would pay higher prices. The market orientation of agricultural production would be more difficult to sustain and consumers' needs would be satisfied by imports. Changing from high intensity to lower intensity farm production increases the penalties on farmers, either from profits foregone, or from the result of higher net costs of production. To provide adequate incomes, producer prices would be higher and there would be a loss of competitive advantage in both the home market and in any potential export market. Little if any land would be surplus to food production requirements, helping to sustain land values at relatively high levels. Consumers are looking for low priced safe food of high quality mainly from multi-outlet grocery chains, which in turn must impose high procurement standards on producers. Currently these standards can only be met with modern 'intensive' production systems, which are not acceptable to the same people in terms of environment and the countryside. Additionally farm incomes are already under pressure and in some rural areas agriculture is still the major industry, employer and provider of wealth.

Land in agricultural production produces economic goods and services, and contributes to the national Gross Domestic Product and to the economic well-being of rural areas. The increasing dependence of agriculture on inputs from outside the farm, (access to fuel, fertilisers and pesticides and external sources of capital) and the fact that most farm production is sold to the non-farm economy, mean that changes in farming impact not only on the associated infrastructure and on food processing and distribution industries, but on the economy as a whole. Changes in the use of land to recreation, wildlife habitats and landscape will reduce the wealth creating capacity of the land. The potential loss of earnings will be the social cost of these benefits. There is very little land in the UK which is not a man-made ecosystem and to maintain the countryside and its appearance, vegetation management of some form or other will have have to be introduced if farming operations disappear. There will obviously be associated costs which may or may not be offset by income from any alternative use of the land. However, the potentially higher productivity of land under modern methods of production does provide the opportunity for striking a new balance in the use of rural land resources, (whether farming or other uses) and the management systems employed.

It must also be recognised that rural land is a decreasing resource because of demands for land for development purposes. Currently the rate of loss in the UK is running at around 14 000 hectares per annum, representing over 30 years a 2.2% reduction of rural land.

AGRICULTURAL TECHNOLOGY

Technology change has been and continues to be, a feature of European agriculture leading to increased output and productivity. Improvements in efficiency have resulted from the intensification of production, and from reduced losses from diseases, pests and weeds in the production systems and in the processing and marketing chains. This results in lower unit costs of production, adequate and reliable supplies of food and in many instances lower consumer prices. However, overall efficiency should be assessed on the true total social costs of agricultural production and there are many different views as to the size of these costs. The inability to quantify environmental costs, the effects on rural communities, the cost to the taxpayer of agricultural policies, the effect of these policies on food prices and on the economies of the UK, the EEC and the rest of the world, make assessment of the total social costs extremely difficult and contentious.

The use of improved genotypes and the realisation of the higher yield potentials have required larger inputs of fertiliser, pesticides and animal feeds. Increased use of capital substituting for labour and land, associated with these higher inputs has substantially increased land and labour productivity, whilst at farm level prices received and the cost of the inputs has in the past produced a favourable financial balance. Economies of scale and specialisation have also contributed to improvements in efficiency and farming prosperity; the average farm size in the UK has increased from 40 hectares in 1965 to 52 hectares in 1985.

The emerging technologies provide the potential for even greater increases in productivity. In the future prosperity of agriculture will depend on achieving improvements in productivity associated with lower unit costs of production. Exploiting the new technologies in situations of competitive advantage will maintain the maximum share in the domestic market and in any export opportunities. The alternative would be higher prices or increased agricultural support and the risk of reduction in the size of the market from import penetration and competition.

In contrast to the past, many of the new technologies will reduce the number and quantities of purchased inputs and reduce input costs, whilst some will decrease environmental hazards associated with current management systems. The total level of resources, land, labour and capital used in food production for any given market size can also be reduced. Inputs of pesticides, machinery and labour will decline per unit of crop and grass production and also in aggregate terms, on a basis of further intensification albeit on a smaller land area. Intensification in grazing animal production systems for a given market size, will require an increase in the use of capital per unit area to support higher stocking densities, balanced against a reduction in the number of breeding animals required to sustain production. Increases in the efficiency of nitrogen fertiliser and some increase in the quantities applied, but not in direct proportion to the increased output, will be essential to support this continued intensification and where production is relocated there may be a need to invest in additional storage. Additionally, the technology can ensure that the producer is more able to meet market requirements including changes in diet and also health standards of food. These developments, whilst making the farm and agriculture more competitive, may not be sufficient to maintain farm incomes. Vertical integration in production and marketing, larger marketing margins and more of the consumer's expenditure going towards packaging, presentation and prepared foods, will continue to put financial pressure on the producer. In the future, these changes will force farmers to strive to maximise their economic returns, generally encouraging a more rapid take up of the new technology. National or Community policies which constrain the application of appropriate new technology will disadvantage the individual farm business and also the nation, in comparison to farms and countries having access to the technology.

CROP PRODUCTION

In the UK over 80% of agricultural land is in cereals or under grass and forage crops for animal production (Table 2). It is changes in the management of these production systems which will have the greatest impact on land use.

TABLE 2 **Land Use UK 1985**

	million hectares
Cereals	
Wheat	1.90
Barley	1.97
Grassland	
Dairy Farms	2.90
Beef and Sheep Less Favoured Areas	6.50
Beef and Sheep Lowland	1.60

Wheat yields have increased by 70% since 1963, an average annual increase of 2.5%; barley yield increase has been less at 40% with a 1.5% annual rate of increase. These compare to rates of increase of 4% in wheat and 2.75% per annum in barley yields over the last decade. Conventional plant breeding methods, increased use of nitrogen fertiliser and improved pest and disease control are likely to sustain yield improvements into the next century at least equivalent to the average 20 year rate of about 2% per annum.

Major developments in cereal production from the new biotechnology will impact around the year 2005. Higher yielding genotypes, improved disease and pest control, more efficient nitrogen fertiliser use and growth regulators will enhance the annual rate of productivity increase to at least 3% per annum. On the assumption that total demand for grain remains at the 1985 level, that the crops are generally located on the more fertile soils and in the more suitable climatic areas, the total area growing cereals will fall substantially to between 1.75 and 2.0 million hectares by the year 2015.

Genotypes resistant to many pests and diseases should be available around the year 2005, whilst biological pesticides will be gradually replacing pesticides based on synthetic chemicals from 1990 onwards. Genetic engineering provides opportunities for increasing the yield potential of crops, optimising the plant and crop canopy structure to maximise light absorption, by improving the efficiency of photosynthetic organs and by improving the partition and use of assimilates towards the economic parts of the plant. In addition, the nutritional or industrial qualities of the plant can be improved e.g. modification of the amino acid spectrum, size and characteristics of starch grains, which will have impacts on food processing, chemical and the pharmaceutical industries. Advances in pest and disease forecasting made possible by computer technology will contribute to more efficient control. Plant growth regulation, either by the application of the regulator to the seed or crop or by genetic modifications can produce new crop possibilities, e.g. a rubber industry in the USA based on the guayule bush and triethylamine growth regulators.

TABLE 3 Introduction of New Cereal Technologies

	Year
Genetic Engineered Plants	2000
Improved stress resistance	1990
Disease and Pest Control	
Biocontrol Agents	1990
Insect and disease resistance in plants	2005
Weed control - biological regulation	1990
Weed control - crop tolerance	1995
Increasing efficiency of nitrogen use	1995
Increasing fertiliser efficiency by microbial agents	2000

GRAZING ANIMAL PRODUCTION

The largest impact on land use derives from changes in the total numbers of grazing animals, stocking densities and the levels of other feeds in the animals' diet. Continued improvements in the milk yield per cow (Table 4) will be available from improved genotypes. The use of multiple ovulation and embryo transplant techniques is likely to double the rate of genotype improvement and sustained by genetic engineering increasing milk production per cow after the year 2005. If demand remains static the number of dairy cows will fall from 3.1 million in 1985 to 1.7 million by 2015.

TABLE 4 **Milk Yields per Cow (UK)**

	Litres
1985	4896
1995	6000
2005	7250
2015	8900

By improvements in pasture yield and utilisation of 2% per annum, stocking rates for dairy cows would rise to 3.4 cows per hectare and for replacement animals to 3.9 units per hectare. The number of replacement animals required will also be reduced by at least 20% as the result of biotechnology developments in fertility, fecundity, sex determination and disease control. The major reduction in grassland requirements for dairy farming is indicated in Table 5.

TABLE 5 Changes in UK Dairy Farming

	1985	2015
Numbers of Cows, millions	3.1	1.7
Numbers of Replacements, millions	1.0	0.4
Grassland Area, million hectares	2.2	0.6

Technological progress in the beef and sheep industry is usually slower than in most other sectors. However genetic improvements, better disease control, improvements in fertility and fecundity, the use of multiple ovulation, embryo transplants, twinning and sex determination all provide the possibilities of large increases in land productivity used for beef production (Tables 6 and 7). The UK national herd could be reduced by 30% by the year 2015 and meet the level of demand in 1985. Improvements in pasture utilisation and feed conversion efficiences will allow improvements in the stocking rate of up to 50%.

In the sheep sector similar improvements will take place, the rearing and fattening of more lambs per ewe will be possible reducing the number of breeding animals. Stocking rates in the lowlands could increase by 50% and in the Less Favoured Areas (LFA), largely the hills and uplands, by up to 20%. Even this figure may prove to be unacceptable for environmental requirements, which may impose lower limits on stocking densities in the LFAs. The sheep population would then tend to move into the lowland areas altering the division of breeding ewes between the LFA and the lowland areas from 60:40 to perhaps 40:60.

TABLE 6 Beef and Sheep Grassland Area, million hectares*

	1985	2015
L.F.A.	6.5	5.2
Lowland	1.7	1.0

* Based on some destocking and movement of sheep from the LFAs to the Lowlands.

All these calculations have ignored a number of significant developments. Genetically engineered bovine growth hormone, subject to national legislation, could be commercially available in the USA in 1987. Milk yields would increase immediately by 25% if this was found acceptable, further reducing the number of cows. Fattening animals also respond by improved growth rates and the production of much leaner carcasses, allowing animals to grow to higher carcase weight with limited fat deposition. In beef animals the growth hormone could increase productivity per fattening animal by 40% and by 25% in sheep. In the longer term these features could be genetically engineered into the animals, which might or might not be acceptable.

TABLE 7 Introduction of New Animal Production Technologies

	Year
Improved fertility	1995
Genetic engineering	2000
MOET, twinning etc.	1990
Improved nutrition and feeding	1995
Control of growth and lactation	1990
Improved disease control	1990

MOET = multiple ovulation and embryo transplants

CHANGES IN DEMAND AND FARM STRUCTURE

These estimates of changes in UK land use have been based on 1985 supplies equating with future demands. Unless improvements in the use of forage for animal feed and acceptable methods for controlling the fat content of red meat emerge, the cereal content of the feed of the grazing animal will be increased to meet higher growth rates and match market requirements. The growth in vegetarian and semi-vegetarian eating could if continued have dramatic effects, as currently 10 times the land area is required to produce the same quantity of food through animals as compared to plant production. Changes in protein quantities and qualities in plants, changes in product processing or developments in single cell protein may further reduce the demand for animal products and adjustments in the cereal to grassland areas.

The world demand for wheat for human consumption, excluding animal feed, has increased substantially over the last 20 years from 71.5 kg per capita in 1965 to 82.9 kg in 1985. Present forecasts for population increase and at current consumption levels, the extra demand could be an additional 120 million tonnes in developing countries by the year 2000. How much of this extra demand would be reflected in increases in world trade and in EEC exports is uncertain; EEC forecasts are generally pessimistic, an increase from 25 million tonnes in 1985/86 to only 26.5 million tonnes in 1991/92. Biotechnology in the processing industries as well as in farm production can lead to future changes in land use. Production of some commodities will increase, others will be substituted. The production of high fructose syrup from maize, wheat or potato starch already provides a cheaper source of sugar. If the granulation problem were solved and the expansion in the use of low calorie sweeteners continues, a cereal for cane and sugar beet substitution is a possibility.

In the longer term as fossil fuel resources are used up and become more expensive, products of current photosynthesis could replace products of historic photosynthesis. The EEC uses 80 million tonnes of oil as chemical feedstocks and 82 million tonnes of petrol per annum, some or all could be replaced by plant products. The storability of cereals and the high potential yields identify wheat as a potential source. Current technology requires 5 tonnes of grain for 1 tonne of 'bio-oil'.

In comparison to the areas of land which could be released from food production, on a national scale opportunities for diversification into new crops or alternative livestock enterprises are extremely limited. The Centre for Agricultural Strategy 1986 considered that an increase in the horse population may use an extra 300 000 hectares, and that an extra 1 million hectares may be devoted to goats and sheep. The milk and milk products from sheep and goats would displace cows milk, hence reduce the area devoted to cows, whilst the sheep kept for milk and fine wool would also produce meat and so displace conventional sheep flocks. The impact on land use would be much less than indicated, but would supply developing markets and reduce imports. In terms of land use the only possibilities in relation to the large areas involved are forests, woodlands and recreational use in the medium term and biomass production in the longer term. Woodlands and recreational use will not however provide similar levels of farm income without substantial government support. On the individual farm the opportunities to take on new enterprises and the effect on farm income may be much greater. New or expanding markets which are currently undersupplied e.g. organic and conservation foods, novel crops will normally attract a premium and individual farmers will benefit, but nationally the opportunities currently appear small. These minor enterprises will create demands on the pesticide industry, though reactions may not be commercially worthwhile. The current shortfall in the production of some vegetable oils and protein seeds in the EEC may in the longer term be satisfied in part by the addition of amino acids to cereals (either directly or by genetic engineering) or by imports, as the world surplus of these products increases in developing countries.

In contrast to the technological changes in the recent past, most of these new developments are scale neutral as regards farm size, that is to say its application is appropriate to both large and small farms. Even so, generally the larger farm tends to be more innovating. It would be expected that the average farm size would continue to grow, partly due to economies of scale, in part by some farmers attempting to increase the size of their income in a cost price squeeze situation. This would continue current trends of an increase in farm size and the need to seek additional income from outside farming on many farms.

Generally it appears that worldwide where trading conditions and political decisions allow, crop production would contract in area and would gravitate towards soils and locations where the high potential of the new genotypes can be exploited. Changes in animal production will be more appropriate to well developed agricultural countries. Economics, in the absence of government interference will also play a part in these adjustments. Low cost producers in any location will still be in a position to compete, subject to the continued availability of supportive infrastructure and suitable market outlets.

FUTURE PATTERNS OF LAND USE

Technology provides an option of improving the economic efficiency of the agricultural industry by reducing the resources of land, labour and capital used for food production and allowing production to be concentrated in the areas of competitive advantage. This will reduce government support, lower the costs of production, extend export market opportunities and could have major beneficial effects on the overall EEC economy and employment outside agriculture. In environmental terms, there would be major beneficial effects; overall the intensity in the use of land for agriculture will be reduced as considerable areas could be released from food production. There will be a reduction in the total input of pesticides and nitrogen fertiliser, lower average land values and less pressure to increase the area under cultivation. On the other hand, continued specialisation and further intensification within the food producing farms will reduce local biological diversity. The distribution of these farms will also be of some significance in environmental terms in areas of potentially high production, but overall land will be available for recreation, wildlife, landscape and for woodland and forestry.

From an individual farmer's point of view, the new technology can increase his competitiveness, maintain or improve his market share, protect his income and allow him to meet market requirements. Many of the improvements involve only marginal cost increases or provide input savings, little or no new investment and will be rapidly taken up. Future reductions in farm cash flows are unlikely to slow the rate of uptake. The less efficient operation is disadvantaged,the numbers of farms and farmers will fall and less people will be employed in the industry. This will also impact adversely on the industries which supply goods and services to agriculture and in some rural areas, the demise of agriculture will seriously reduce their viability.

The alternative to the efficient solution must be based on social considerations. The 'value of the family farm' in social terms and large numbers of people working in agriculture and in ancillary industries, would be sustained on the basis of the favourable impact on the 'well-being' of the rural areas and the nation. It would involve protection of the industry against economic and commercial pressures and a continuing transfer of wealth to the farm sector from elsewhere in the community. Generally it discriminates against progressive farmers and farming, and imposes unnecessary burdens on the taxpayer.

'Set aside' as practiced in USA, Canada and Finland designed to reduce supplies has only been partially successful and has also increased the amount of government support to agriculture. These programmes are often associated with an increase in grazing livestock, products which are already in surplus production in the EEC with the exception of mutton and lamb. 'Set aside' in the EEC is being promoted in terms of supply reduction and savings in intervention costs and export subsidies. These savings balanced against the additional costs of protecting farm incomes may reduce the costs of market support, but the savings may be insufficient in terms of the overall EEC budget.

The EEC 'guidelines' published in January 1986 called for actions in a number of priority areas which will influence land use options. Alignment of production to market demands in quantity, quality and price terms would favour movement towards the efficient solution, as would the development of industries to process agricultural produce. Proposals to deal effectively with the income problems of small farms and supporting agriculture in areas to maintain social balance, protect environment and landscape require a protectionist approach.

In the UK a 'protectionist policy' would largely be orientated to the Less Favoured Areas, where the land is used for sheep and beef production, the 6.5 million hectares previously identified. This would slow down the movement of sheep production into the lowlands if financial support in the LFAs remained substantial. However for environmental reasons some destocking is likely to take place. The proposals to reduce production of commodities in surplus, unless based on a non-transferable quota, will speed up the concentration of production on farms having a comparative advantage. Even without EEC action, these trends would be followed catalysed by the uptake of new technology.

IMPACT ON PESTICIDE USE

Pesticides are used and will continue to be used in the majority of systems of land management, whether the land use is in agriculture, forestry, recreation or for environmental purposes. A reduction in the area of land devoted to food production will more or less **pro rata** decrease the total amount of pesticide input into this sector. The more intensive production systems may or may not require increased pesticide input as and when new problems arise. Pesticide developments producing more effective treatments involving formulations, delivery systems and better forecasting; the trends are already moving towards reductions in the rates of application and more environmentally safe materials. Generally other uses of land require lower pesticide inputs, even lower than the current pesticide use on crops in marginal areas, so that the total pesticide usage will be less. Changes in the economic relationships in farming systems will also mean adjustments probably favouring lower pesticide inputs. The future size of the woodland and forestry areas will be of considerable importance to the pesticide industry as will the developments in biomass production. As forestry expansion is almost entirely dependent on legal, fiscal and government support arrangements, it is impossible to forecast the extent of any developments. Timber production from existing areas may double by 2000, but even so the UK will only be 20% self sufficient. Growing wood for fuel, for particle board or pulp on better quality land produces useful returns within a short space of time, 3 to 4 year as compared to in excess of 20 years for conventional timber production. This involves high density plantings, rotational harvesting on a 3 or 4 year cycle and is a system akin to arable silage production. In addition juvenile wood chips can be converted to gas or liquid fuel. Agroforestry attempts to overcome the cash flow problems of timber production, silvopasture systems, grazing animals and 'widely' spaced trees, have a place in the hill areas and may be appropriate to some lowland conditions.

Pesticide manufacturers now have substantial investments in plant breeding and seed multiplication facilities, furthering the integration of genetic resistance with pesticide control. Growth regulation by chemicals produced by the industry supplement changes in crop plants and crop management arising from plant breeding. Biological control methods are gradually replacing synthetic chemicals increasing the cost effectiveness of plant protection whilst reducing the risks of pesticide tolerance and being more environmentally acceptable. Genetic engineering in the longer term will provide increased, durable disease resistance, although this will not always be complete, requiring supplementation and integration with pesticides. In the very long term durable immunity to disease and pests may be achieved.

Increased herbicide tolerance in crop plants is now possible by the use of so called chemical safeners, and eventually will come through genotype. This will widen the choice of weed management systems and herbicide selection, again improving cost effectiveness and environmental acceptability. Reduction of stress damage and improvements in soil fertility and fertiliser efficiency from microbial inocula are all possible, presumably provided by the pesticide industry. Some of the biological methods will be more cost effective in monoculture situations and may themselves influence land use.

CONCLUSIONS

The application of new technology will provide opportunities for major changes in land use arising from improvements in land productivity. Crop production will become more intensive, the land released being used for timber and biomass production, recreation, wildlife conservation and landscape. Total pesticide use will decline considerably. In the LFAs, however, extensive livestock systems will be maintained for social needs, in some areas associated with agroforestry.

SESSION 2A

NEW COMPOUNDS, FORMULATIONS AND USES (FUNGICIDES)

CHAIRMAN	DR D. RUDD-JONES	
SESSION ORGANISERS	DR F. M. HUMPHERSON-JONES DR A. R. THOMPSON	
RESEARCH REPORTS		2A-1 to 2A-9

HEXACONAZOLE : A NOVEL TRIAZOLE FUNGICIDE

M.C.SHEPHARD, R.A.NOON, P.A.WORTHINGTON, W.D.McCLELLAN, and B.G.LEVER

ICI Plant Protection Division, Jealott's Hill Research Station, Bracknell, Berkshire, RG12 6EY

ABSTRACT

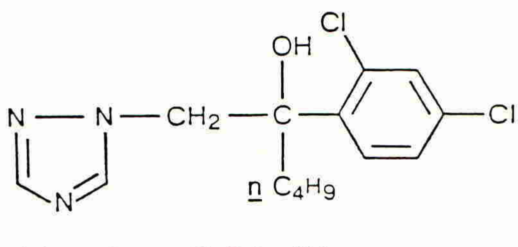
Hexaconazole is a new triazole fungicide with low mammalian toxicity and an exceptionally broad spectrum of anti-fungal activity. Its outstanding protectant activity, combined with curative, translaminar, antisporulant and systemic properties, enable it to be used effectively against diseases of many crops at very low application rates. Glasshouse data are presented to illustrate its spectrum of activity and important properties. Field results demonstrate its excellent performance against diseases of vines, apples, peanuts and coffee.

INTRODUCTION

Hexaconazole (PP523) is the BSI and proposed ISO common name for (*RS*)-2-(2,4-dichlorophenyl)-1-(1*H*-1,2,4-triazol-1-yl)hexan-2-ol. It is a new, highly active, broad spectrum fungicide synthesised at the Jealott's Hill Research Station of the Plant Protection Division of ICI. It is formulated as a suspension concentrate (50g a.i./l) and as a soluble grain (50g a.i./kg) which are marketed under the tradename 'Anvil'.

CHEMICAL AND PHYSICAL PROPERTIES

Structural formula :



Molecular formula and weight : $C_{14}H_{17}Cl_2N_3O$; 314.

Appearance and melting point : white crystalline solid, m.p. 111°C.

Density : 1.29g/cm^3 at 25°C.

Vapour pressure : 2 x 10^{-8} kPa at 20°C.

Solubility (g/l at 20°C) : water 0.017, methanol 246, acetone 164, toluene 59, hexane 0.8.

Stability : stable for at least 9 months at ambient temperatures.

TOXICOLOGY AND ENVIRONMENTAL STUDIES

Hexaconazole has low toxicity to mammals, birds, fish, bees and other wildlife species. It is classified as a mild eye irritant but is non-irritant to the skin. It is readily excreted by mammals with no significant retention in organs or tissues. It is not mutagenic.

TABLE 1

Toxicology data

Acute toxicity		Species	Rate	
Oral	LD_{50}	Rat (Male)	2,189	mg/kg
Oral	LD_{50}	Rat (Female)	6,071	mg/kg
Dermal	LD_{50}	Rat	>2,000	mg/kg
Oral	LD_{50}	Mallard Duck	>4,000	mg/kg
Contact	LD_{50}	Honey Bee	>100	µg/bee
96 h	LC_{50}	Rainbow Trout	>6.7	mg/l

Residues of hexaconazole in crops treated at recommended rates have been very low (<0.01-0.03 mg/kg). Degradation in laboratory soils is rapid and mobility through soil is low.

BIOLOGICAL ACTIVITY

Materials and methods

The activity of hexaconazole was observed *in vitro* after 3-10 days growth on treated agar. For glasshouse tests *in vivo*, the foliage of small seedlings, and/or the compost was treated with hexaconazole before or after inoculation. After incubation, the amount of disease was assessed as a percentage of that on the untreated.

All field tests had treatments arranged in 4 randomised blocks. Plot sizes varied with the crop: vines, 7-15 plants; apples, 1-5 trees; coffee, 5 hills x 2 plants; peanuts, 4 rows x 6m. Hexaconazole was applied at 2000l/ha to apples; 400-2000l/ha high volume, or 150-400l/ha with air blast, to vines; 250l/ha with air blast to coffee; and at 160l/ha using a field crop sprayer for peanuts. Timing followed the normal grower practices for the area. The numbers or percentage area of leaves or fruit infected were assessed. Coffee and peanut leaves were classified as healthy, infected, or missing, (so that defoliation was included).

Statistical analysis was by analysis of variance and restricted LSD. In the Tables, values in the same group of data followed by a common letter are not significantly different at $P = 0.05$.

Results

Laboratory and Glasshouse Studies

Hexaconazole inhibited the growth of a broad spectrum of fungal pathogens (Table 2). It had little activity against Oomycete fungi or bacterial pathogens. It was a potent inhibitor of C14-demethylation during the synthesis of ergosterol by *Ustilago maydis* (Wiggins 1986).

TABLE 2

Spectrum of activity in laboratory and glasshouse tests

Organism	Activity[1] in vitro 10mg/l	Activity[1] in vivo ≤100mg/l	Organism	Activity in vitro 10mg/l	Activity in vivo ≤100mg/l
Alternaria solani	4	4	*Pseudocercosporella herpotrichoides*	-	4
Ascochyta pisi	4	-	*Puccinia recondita*	-	4
Cercospora arachidicola	-	4	*Pyrenophora teres*	-	3
Colletotrichum coffeanum	4	-	*Pyricularia oryzae*	4	2.5
Diaporthe phaseoli	4		*Rhizoctonia solani*	-	2
Erysiphe graminis	-	4	*Rhynchosporium secalis*	-	4
Fusarium culmorum	3	2	*Sclerotinia sclerotiorum*	4	-
Gaeumannomyces graminis	-	4	*Sclerotium rolfsii*	4	-
Geotrichum candidum	4	-	*Septoria nodorum*	-	4
Helminthosporium oryzae	4	-	*Sphaerotheca fuliginea*	-	4
Nectria galligena	2	-	*Uncinula necator*	-	4
Penicillium digitatum	4	-	*Venturia inaequalis*	-	4
Phoma exigua	4	-	*Verticillium albo-atrum*	3.5	-
Podosphaera leucotricha	-	4			

[1] 0-4 scale where 0 = >60% and 4 = no fungal growth or disease

In glasshouse tests hexaconazole was consistently more effective than standard compounds. Very high levels of activity were detected against vine powdery mildew (*Uncinula necator*) and early leaf spot of peanuts (*Cercospora arachidicola*) (Table 3). Curative activity was outstanding, extending over 4 days against apple scab (*Venturia inaequalis*) and over 14 days against coffee rust (*Hemileia vastatrix*) (Table 3).

TABLE 3

Protectant and curative activity of hexaconazole (Hc), triadimefon (Tr), benomyl (Bn) and penconazole (Pc) in the glasshouse

Protectant sprays						Curative sprays					
U. necator			*C. arachidicola*			*V. inaequalis*			*H. vastatrix*		
Dose mg/l a.i.	1 day[1] % control Hc	1 day[1] % control Tr	Dose mg/l a.i.	1 day[1] % control Hc	1 day[1] % control Bn	Dose mg/l a.i.	4 days[1] % control Hc	4 days[1] % control Pc	Dose mg/l a.i.	14 days[1] % control Hc	14 days[1] % control Tr
25	-	99d	10	99b	99b	15	91cd	91cd	100	-	85b
5	-	42bc	2.5	97b	95b	5	96d	91cd	30	92b	-
1.0	99d	18ab	1.0	82b	-	1	71c	28b	10	91b	62b
0.3	77c	-	-	-	-	-	-	-	3	91b	-
0	0a (90)		0	0a (100)		0	0a (84)		0	0a (89)	

[1] interval between application of chemical and inoculation
( ) = % disease on untreated

On peanuts, inoculated from below, and sprayed from above at 250 l/ha 7 days later, lesion development and sporulation were almost completely inhibited by 50g a.i./ha (Table 4). When applied to the roots of vine seedlings which were inoculated 13 days later, powdery mildew was controlled on the new leaves (Table 4). When applied to a band across the centre of an apple leaf, movement within the leaf and external redistribution provided excellent protection of the distal untreated area and moderate protection of the proximal area (Table 5).

TABLE 4

Translaminar and root drench activity in the glasshouse

Dose (mg/l a.i.)	Translaminar spray C. arachidicola % control lesions Hc	Translaminar spray C. arachidicola % control sporulation Hc	Dose (mg/l a.i.)	Root drench U. necator % control leaf disease Hc	Root drench U. necator % control leaf disease Pc
50	87c	99b	25	99c	84c
13	72bc	76b	5	93c	36ac
3	43b	57b	1	64c	17ab
0	0a	0a	0	0a	
	(60)	(X)		(72)	

(X) = 350 x 10^3 spores per plant.

TABLE 5

Movement across apple leaves in the glasshouse

Dose mg/l a.i.	% control of V. inaequalis on each part of the leaf: Proximal Hc	Proximal Pc	Treated[1] Hc	Treated[1] Pc	Distal Hc	Distal Pc
25	-	3a	-	100c	-	53b
15	38b	3a	100c	84b	100c	33b
7.5	48b	-	100c	-	45b	-
0	0a		0a		0a	
	(97)		(94)		(72)	

[1] = 10 x 2ul droplets in band across leaf (1 day protectant)

Field Trials

Vines

In field trials on vines over a 5 year period, the control of powdery mildew on leaves and bunches has been outstanding (Table 6). Coupled with this, the activity against black rot (Guignardia bidwellii) was higher than that with any of the standards (Table 7). A dose of 1.5 - 2.0g a.i./hl was adequate to control a heavy epidemic of either disease. More details of these trials are given by Heaney et al (1986).

TABLE 6

Control of powdery mildew on vines (1982-85)

Treatment	Dose (g a.i. /hl)	% Disease Control[1]: Leaf mildew (area) USA 1983 7DAT3[2]	Leaf mildew (area) France 1984 8DAT7	Leaf mildew (area) France 1985 14DAT4	Bunch mildew (area) Spain 1982 13DAT3	Bunch mildew (area) USA 1983 7DAT3	Bunch mildew (area) France 1984 14DAT8	Bunch mildew (area) France 1985 2DAT
Hexaconazole	0.6	99b	-	-	100c	98b	-	-
"	0.8	-	-	-	-	-	-	-
"	1.0	-	98b	-	-	-	100b	-
"	1.25	99b	99b	100d	100c	100c	100b	99b
"	1.5	-	100b	99c	-	-	100b	100b
Fenarimol	1.2	99b	-	91b	95bc	97b	-	99b
Penconazole	1.5	-	98b	99c	-	-	99b	99b
Untreated	-	0a	0a	0a	0a	0a	0a	0a
		(30)	(40)	(43)	(50)	(100)	(42)	(59)

1 = based on the numbers or area of leaves or fruit infected
2 7DAT3 = 7 days after the third application; spray interval 14 days

TABLE 7

Control of black rot on vines (France 1985)

Treatment[1]	Dose g a.i./hl	% Disease Control: Trial A leaf (nos) 6DAT6	Trial A bunch (area) 15DAT13	Trial B leaf (nos) 14DAT1	Trial B bunch (area) 28DAT8
Hexaconazole	1.5	90b	99c	94b	72bc
"	2.0	97b	100c	87ab	85cd
Hexaconazole + folpet + captafol	1.5+96+24	95b	100c	96b	89d
Mancozeb	280	63a	71a	100c	49a
Folpet + captafol	160+40	67a	86b	100c	65ab
Cymoxanil + propineb + triadimefon	12+145+5.0	96b	100c	59a	87d
Triadimefon	5.0	-	-	70a	52a
Untreated	-	0	0	0	0
		(82)	(74)	(14)	(60)

1 Spray schedule : A: 8-15 days (on warning); B: 12-16 days (calendar)

Apples

Hexaconazole at 10-20mg/1, alone or in mixture with a dithiocarbamate, gave excellent control of apple scab and mildew (Podosphaera leucotricha) (Table 8). In a trial in the USA, cedar apple rust (Gymnosporangium juniperi-virginianae) was also controlled very effectively.

TABLE 8

Control of powdery mildew and scab on apples (1984)

Treatment	Dose mg/1 a.i.	% Disease Control					
		Powdery mildew		Scab			
		UK		France		Italy	Holland
		Pri-mary 8DAT4	Secon-dary 7DAT9	leaf (nos) 7DAT4	fruit (area) 19DAT8	fruit (nos) 11DAT6	fruit (nos) 28DAT10
Hexaconazole	7.5	-	-	84bc	92b	-	-
"	10.0	85b	71b	92c	92b	-	100c
"	15.0	-	-	92c	85b	-	100c
"	20.0	93b	90c	99d	88b	97c	100c
Hexaconazole + dithiocarbamate	10+800	-	-	-	-	93bc	-
"	15+800	-	-	-	-	-	99bc
Fenarimol	36-40	95b	76b	85bc	88b	-	-
Fenarimol + dithiocarbamate	42+800	-	-	-	-	86b	-
Penconazole	25	91b	88c	86bc	87b	-	-
Bitertanol	125	-	-	-	-	-	99bc
Untreated	-	0a (38)	0a (89)	0a (85)	0a (6.7)	0a (65)	0a (62)
Cultivar		------------Golden Delicious------------					Mantet

Peanuts

On peanuts in the USA, Malaysia and Brazil, hexaconazole, either alone or in combination with low rates of chlorothalonil, has given excellent control of both early and late leaf spot (Cercosporidium personatum), (Table 9). Yields were superior to the standard chlorothalonil treatment.

Coffee

Against coffee rust, the long term curative effects are particularly useful. In 1985, with a fairly late epidemic in Brazil, three sprays with 30g hexaconazole/ha were at least as effective as five copper sprays and slightly superior to three sprays of 250g triadimefon/ha. With a four spray programme, a dose of 10g hexaconazole was as effective as 250g triadimefon (Table 10).

TABLE 9

Control of early and late leaf spot of peanuts in 1984 in Georgia (GA), Florida (FL) and North Carolina (NC)

Treatment	Dose (g a.i. /ha)	Healthy Leaves[1]			Yield[2]		
		GA	FL	NC	GA	FL	NC
Hexaconazole	22	79b	77b	67b	121	107b	86ab
"	45	90bc	81b	80de	96	107b	104c
"	67	94c	87b	86de	116	120c	106c
Hexaconazole + chlorothalonil	22+561	93c	81bc	79ce	107	105b	97bc
"	45+561	89bc	87c	85de	111	119c	102c
Chlorothalonil	1122	92bc	75b	78bd	100 (4.4)	100b (4.1)	100bc (5.0)
Untreated	-	18a	0.1a	4.4a	85	76a	71a

1 = % leaflets present and healthy 1 week before harvest
2 = Yield expressed as % of chlorothalonil treatment
( ) t/ha.

TABLE 10

Control of coffee rust with hexaconazole (Brazil 1985)

Treatment	Dose (g a.i. /ha)	Timing[2]	% Healthy leaves		
			Base of shoot 93DAT5	Middle of shoot 154DAT5	Tip of shoot 154DAT5
Hexaconazole[1]	30	T2-5	79f	74cd	96e
"	20	T2-5	80f	74cd	96e
"	10	T2-5	74df	70cd	93ce
"	30	T3-5	74df	77d	96e
Copper oxychloride	1500	T1-5	67ce	72cd	87c
Triadimefon	250	T2-5	73df	71cd	91ce
Triadimefon	250	T3-5	65bd	65c	87c
Untreated	-	-	20a	15a	57a

1 500mg/l 'Agral' added to spray tank
2 T1 = Jan 9; T2 = Jan 29; T3 = Feb 21; T4 = Mar 19; T5 = Apr 16

Other Crops

In widespread field tests hexaconazole had unusually broad activity against most diseases controlled by inhibitors of sterol biosynthesis. On bananas, 30-60g a.i./ha gave excellent control of Black Sigatoka (*Mycosphaerella fijiensis* var *difformis*); on peaches 20-50mg/l a.i. showed high activity against brown rot (*Monilinia fructicola*), scab (*Cladosporium carpophilum*) and powdery mildew (*Sphaerotheca pannosa*); and against diseases of vegetables, citrus, soft fruit and roses hexaconazole has shown useful activity.

Crop safety

Hexaconazole has been used safely on leading commercial varieties of many crops under a range of climatic conditions. There has normally been a clear margin of safety between rates required for disease control and those which may damage the crop.

CONCLUSIONS

Hexaconazole, with its outstanding activity against a wide variety of diseases and its penetrant, curative, systemic, and antisporulant properties, provides a useful addition to the range of commercial fungicides available. Application rates are expected to be lower than those for many triazole fungicides. On some crops hexaconazole alone will provide protection against all the major diseases. It is, however, compatible with dithiocarbamates and chlorothalonil and can be mixed with these or other suitable co-fungicides where this is desirable e.g. to avoid development of resistance.

Most of the experiments described here have used traditional spray schedules. However, with a versatile compound such as hexaconazole, new weather-based schedules may be feasible for regions with relatively few infection periods, or on crops such as coffee where the disease develops relatively slowly.

ACKNOWLEDGEMENT

The authors wish to acknowledge the contributions of colleagues within ICI who have provided data or helped with the preparation of this paper.

REFERENCES

Heaney, S.P.; Atger, J.C.; Roques, J.F.; (1986) Hexaconazole: A novel fungicide for use against diseases on vines. Proceedings 1986 British Crop Protection Conference - Pests and Diseases (In press).

Wiggins, T.E.; (1986) personal communication.

FENPROPIDIN, A NEW SYSTEMIC CEREAL MILDEW FUNGICIDE

K. BOHNEN, A. PFIFFNER, H. SIEGLE, P. ZOBRIST

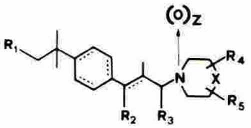
Dr. R. Maag Ltd., CH-8157 Dielsdorf, Switzerland

ABSTRACT

Fenpropidin, (RS)-1-[3-(4-*tert*-butylphenyl)-2-methylpropyl]piperidine, is a new, specific cereal fungicide which provides:
safe control of *Erysiphe graminis* on barley and wheat at 500 - 750 g a.i./ha; good control of cereal rust diseases; a strong and rapid curative effect; optimal persistence over *c.* 4 weeks; biological activity independent of temperature variations.
Fenpropidin is a 'two-site' inhibitor fungicide that blocks the Δ14-reductase and the $\Delta 8 \rightarrow \Delta 7$-isomerase in the ergosterol biosynthetic pathway, and thus differs from the entire group of commercially available cereal fungicides that inhibit the C14-demethylase in the same biosynthetic sequence.
Seven years of field trials have shown that, on the basis of its biological properties, environmental behaviour, and particular mode of action, fenpropidin is a very promising fungicide. Furthermore, it can be valuable in the establishment of desirable strategies to lower risks of resistance development and in the solution of specific problems in the control of cereal diseases, such as: systemic control of cereal mildew strains that have altered their sensitivity; as a partner for cereal mildew fungicides with other modes of action for alternating spray applications and combining products; to counter resistance development; and as a combination partner for fungicides with which additional and increasingly important cereal diseases may be controlled in the future.

INTRODUCTION

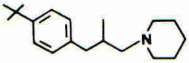
During lead investigations with growth regulators for the production of more compact plants (Hüppi *et al.*, 1976), the fungicidal side effects of certain compounds led us to a new chemical class. Molecules with the general structure



in which	R1	is substituted by H, alkyl, cycloalkyl (to 8C), aryl, or halogen
	R2-R5	by H, alkyl (1-8C)
	X	by CH_2 or O and
	Z	is zero or one

proved to be eminently suitable for the control of mildew and rust diseases on cereals. Fenpropimorph, the first analogue from this chemical class (Bohnen and Pfiffner, 1979) and introduced in 1980, has been used successfully on cereals, even under conditions of extreme infection pressure.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name (IUPAC)	:	(RS)-1-[3-(4-*tert*-butylphenyl)-2-methylpropyl] piperidine
Structure	:	
Molecular formula	:	$C_{19}H_{31}N$
Code number	:	Ro 12-3049
Common name	:	fenpropidin
Molecular weight	:	273.46
Density (20°C)	:	0.91 kg/l
Boiling point	:	100°C / 4 x 10^{-3} torr
Vapour pressure (25°C)	:	1.58 x 10^{-4} torr
Solubility	:	in water (20°C): $<$1 g/l at pH $>$ 7; soluble in organic solvents
Appearance	:	pale yellow, slightly viscous liquid
Stability	:	stable at room temperature
Odour	:	odourless

TOXICOLOGY

Acute toxicity	:	LD50 oral rat	:	1800	mg/kg
		LD50 dermal rat	:	$>$1800	mg/kg
		LD50 intraperitoneal rat	:	350	mg/kg
		LC50 inhalation rat	:	1.2	mg/l
Sensitization	:	no skin sensitizing potential (guinea pig)			
Skin + eye irritation	:	irritant of skin (rabbit, guinea pig) and of eye (rabbit)			
Mutagenicity	:	no mutagenic potential			
Teratogenicity	:	no teratogenicity or mother-toxic effects			

WILD LIFE HAZARD STUDIES

Birds	:	LD50 oral mallard duck	:	1900	mg/kg
		LD50 oral pheasant	:	370	mg/kg
Aquatic organisms	:	LC50 (96 h) rainbow trout	:	2.5	mg/l
		mirror carp	:	3.5	mg/l
		bluegill sunfish	:	1.9	mg/l
		EC50 (48 h) daphnia	:	0.5	mg/l
Honey bees	:	LD50 (48 h) oral (highest possible conc.)	:	$>$ 0.01	mg/bee
		LD50 (48 h) contact	:	0.046	mg/bee

ENVIRONMENTAL CHEMISTRY

Soil	:	Extensive degradation was proven by $^{14}CO_2$ production. Fenpropidin and its metabolites show little or no tendency to leach.
Plants	:	Relatively rapid and extensive degradation. Half-life in barley and wheat plants: 4 - 11 days.
Animals	:	Rapid metabolism and elimination in rat through urine and feaces after oral uptake. Fenpropidin and its metabolites do no present a cumulative hazard in animals since no significant bioretention was observed.

BIOLOGICAL ACTIVITY

Spectrum of activity

The main activity of fenpropidin is specifically directed towards the pathogens causing cereal mildew. The strong side effect of fenpropidin on treated cereals affords extensive control of rust diseases caused by *Puccinia* species.

Of the additional side effects listed in Table 1, that against *Ceratocystis ulmi* (Dutch elm disease) is under field investigation.

TABLE 1

Fenpropidin : Spectrum of activity

		Field g a.i./ha or /kg seed		Laboratory LC 50 (mg a.i.)
Main activity				
Erysiphe graminis	barley	500 - 750	xxx	
E. graminis	wheat	500 - 750	xxx	
Puccinia hordei	barley	750	xx	
P. striiformis	wheat	750	xx	
P. recondita	wheat	750	xx	
P. graminis	wheat	750	xx	
P. coronata	oat	750	xx	
Side effects				
Rhynchosporium secalis	barley	750	x	
Hemileia vastatrix	coffee	1000 - 2000	xx	
Helminthosporium gramineum	seed	1	xxx	
Poria placenta	agar			0.2
Ceratocystis ulmi	agar			0.2
Penicillium digitatum	agar			0.5
Alternaria solani	agar			0.6
Colletotrichum lindemutheanum	agar			1.8
Lenzites trabea	agar			2.5
Chaetomium globosum	agar			3
Cladosporium cucumerinum	agar			3
Ustilago maydis	agar			5
Piricularia oryzae	agar			5
Aspergillus niger	agar			10
Gaeumannomyces graminis	agar			10
Monilia laxa	agar			10
Pseudocercosporella herpotrichoides	agar			20
Pellicularia rolfsii	soil			25

xxx : ≥90% control
xx : ≥75% control
x : <75% control

Field trials

Since 1978, fenpropidin has been tested in more than 100 field trials in the most important cereal-producing European countries using plot sizes of 10 - 40 m2 and four to five replicates. A 750 g/litre EC formulation of fenpropidin was used; commercial formulations of other fungicides as standards for comparison were used.

Barley mildew

Single treatments with 500 -750 g fenpropidin/ha at the beginning of infestations gave good control comparable to the standards fenpropimorph (750 g/ha) and triadimefon (125 g/ha). Yield increases at 15 - 20% infestation were generally equal to or slightly above standard (8% or more in winter barley and 6% or more in spring barley). The eradicative effect with 750 g fenpropidin/ha was rapid and strong.

Wheat mildew

Excellent control (generally above 90%) was given with single applications on leaves and ears at doses from 500 g fenpropidin/ha upward. Early or persistent infestation pressure required additional treatments. Yield increases with infestations higher than 25% were on average c. 8%. Strong eradicative effects were noted. The highest fenpropidin activity in cereals was recorded in those areas where triazole fungicides were predominantly and repeatedly applied.

Rust diseases on barley and wheat caused by Puccinia species

The side effect against rust diseases observed in the cereal mildew control at 500 - 750 g fenpropidin/ha was good but less than that of fenpropimorph at 500 - 750 g a.i./ha or triazole standards at 125 g a.i./ha. Infestations can be maintained below the damage threshold in seasons with mild or medium infection pressure. Early infestations or strong infection pressures require one to two additional fenpropidin treatments at 750 g a.i./ha.

Barley leaf blotch (Rhynchosporium secalis); glume blotch (Septoria nodorum)

Fenpropidin side effects are weak and insufficient for control. Excellent results were obtained with combinations containing fenpropidin and fungicides with strong, specific activity. The aim of these continuing trials is the control of the most important cereal diseases with one product.

Fungicidal persistence

Fenpropidin applications protect cereal crops under field conditions, independently of temperature and with 4 to 5 weeks against *E. graminis* at 0.5 - 0.75 kg a.i./ha and 3 to 4 weeks against *Puccinia* species at 0.75 kg a.i./ha.

Uptake and transport in plants

Fenpropidin is quickly absorbed by the roots and, to a minimal extent, by the rest of the plant. Acropetal translocation in the plant is in the xylem with the transpiration flow. Basipetal transport was not detected.

Biological activity via the vapour phase

Fenpropidin shows a strong secondary dispersion through the vapour phase. In the greenhouse, *E. graminis* infections on wheat and barley were completely suppressed if the neighbouring cultures were treated with fenpropidin at a distance of up to 1 m. In the field, the spread of mildew on the borders of untreated small field plots was reduced by up to 30% if the neighbouring plot was treated with fenpropidin.

Mode of action

Fenpropidin inhibits the ergosterol biosynthesis pathway of sensitive fungi at two essential steps, i.e. by blocking the △14-reductase, as well as the △8→△7-isomerase (Baloch & Mercer, in preparation). Fenpropidin and the related fenpropimorph, as well as tridemorph, thus differ from the introduced, systemic triazole and imidazole cereal fungicides that inhibit the ergosterol biosynthesis at the C14-demethylation step (Baloch *et al*., 1984). Based on this double block in the sterol biosynthesis shunt, the development of resistant pathogens is impeded and a longer life span for representatives of this chemical class can be forecast.

After preventive fenpropidin applications at 50 mg/litre in the greenhouse against barley mildew, conidial germination was practically unaffected, the development of appressoria was moderately checked (by *c.* 20%) and the formation of secondary hyphae 24 - 32 h after germination, and therefore colonization of the host, was completely blocked (by *c.* 99%).

After curative applications at 50 mg/litre in the greenhouse against barley mildew, the hyphae at the periphery of the infection site rise from the epidermis, swell, and subsequently collapse, and mycelium, conidia, and basal cells developed before treatment lose their turgor, collapse and wither. The focus of infection is extinguished.

CONCLUSIONS

With 1 to 2 foliar applications per season at 500 - 750 g a.i./ha, fenpropidin gave excellent control of cereal mildews. Simultaneously, treated cereal was well protected from rust diseases caused by *Puccinia* species.

The rapid and strong curative effect of fenpropidin permits the initiation of treatment against mildew after the appearance of the first disease symptoms in the crop.

A long life span of fenpropidin can be forecast as its mode of action, which blocks the ergosterol biosynthesis at two sites, impedes the formation of resistant *E. graminis* and *Puccinia spp.* strains.

Desired anti-resistance strategies result from the alternating or simultaneous application of fenpropidin or fenpropimorph and suitable representatives of cereal fungicides that block the C14-demethylase.

The specific action, curative effects and optimal, limited persistence of fenpropidin make it an interesting partner for combination products whose spectrum will thus allow the control of other, increasingly important cereal diseases.

REFERENCES

Baloch, R.I.; Mercer, E.I. (in preparation) Inhibition of △8→△7-isomerase and △14-reductase by fenpropimorph, tridemorph and fenpropidin in cell-free enzyme systems from *Saccharmyces cerevisiae*.

Baloch, R.I.; Mercer, E.I.; Wiggins, T.W.; Baldwin, B.C. (1984) Inhibition of ergosterol biosynthesis in *Saccharomyces cerevisiae* and *Ustilago maydis* by tridemorph, fenpropimorph, and fenpropidin. *Phytochemistry* 23, 2219-2226.

Bohnen, K.; Pfiffner, A. (1979) Fenpropimorph. A new systemic fungicide for the control of powdery mildew and rust diseases of cereals. Proceedings of the IX International Congress of Plant Protection and 71st Annual Meeting of the American Phytopathology Society., Washington, August 5 - 11, 1979, Ref. No. 307.

Hüppi, G.A.; Bocion, P.F.; de Silva, W.H. (1976) A new quaternary ammonium compound with plant growth regulatory activity. Experientia 32, 37.

SAN 619 F, A NEW TRIAZOLE FUNGICIDE

U. GISI, F. SCHAUB, H. WIEDMER, E. UMMEL

Agrochemical Division, SANDOZ Ltd., CH-4002 Basel, Switzerland.

ABSTRACT

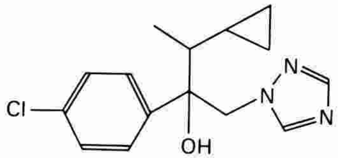
SAN 619 F is a new broad spectrum triazole fungicide with excellent activity against diseases caused by powdery mildews, Monilinia, Cercospora, Venturia, rusts, Rhizoctonia, Sclerotium and with additional activity against Septoria, Helminthosporium and Guignardia. SAN 619 F penetrates into the plant tissue very rapidly and is translocated acropetally. SAN 619 F shows long lasting preventive and curative activity and interesting eradicative activity. At rates of 40 to 100 g a.i./ha or 0.8 to 1.5 g a.i./hl (depending on crop), SAN 619 F, used alone or in mixture with other fungicides, provides excellent disease control and significant yield increase under different field conditions; it was generally well tolerated by all crops. Field testing with SAN 619 F showed very high and long lasting activity against rust diseases of cereals and coffee, powdery mildews of cereals, fruit trees and grapes, leaf spot diseases of peanuts and sugarbeets, apple scab and white mold of peanuts. When used in mixtures with other fungicides, good activity has also been found on cereal eyespot (Pseudocercosporella), leaf blotch (Septoria and Rhynchosporium) and net blotch (Pyrenophora).

INTRODUCTION

SAN 619 F is a new broad spectrum triazole fungicide discovered and patented by SANDOZ Ltd., Switzerland. It is available in a range of formulations either alone (100 SL, 10 WP, 10 WG, 40 WP, 40 WG) or in combination with other appropriate fungicides for use in cereals, grapes, fruit trees, sugarbeet, peanuts, vegetables, rice, ornamentals, turf and tropical trees. This paper describes the properties of SAN 619 F under laboratory, greenhouse and field conditions.

CHEMICAL AND PHYSICAL PROPERTIES

Structural formula



Molecular formula and weight	$C_{15}H_{18}ClN_3O$, 291.78
Development code number	**SAN 619 F**
Chemical name	(2 RS, 3 RS)-2-(4-chlorophenyl)-3-cyclopropyl-1-(1H-1,2,4-triazol-1-yl)butan-2-ol
Physical state	crystalline solid, colorless
Melting point	103 - 105°C
Solubility (% w/w at 25°C)	in water 0.0140±0.0004; in acetone >23; in ethanol > 23; in xylene 12, in DMSO >18
Vapour pressure	2.6×10^{-7} Torr at 20°C
Partition coefficient p	819±195

TOXICOLOGY AND RESIDUES

SAN 619 F has a relatively low acute oral toxicity (LD_{50} rat: 1020 mg/kg for male and 1330 mg/kg for female) and a low acute dermal toxicity (LD_{50} rat: higher than 2000 mg/kg). It is not irritant to the skin or eyes (rabbit) and does not cause skin sensitization (guinea pig). In several standard tests (including Ames test), SAN 619 F did not show any mutagenic potential. SAN 619 F shows low to moderate fish toxicity (LD_{50} carp: 18.9 mg/l, trout 7.2 mg/l, bluegill sunfish 6.0 mg/l in water) and low bird toxicity (LD_{50} bobwhite quail: oral 150 mg/kg and 8-day dietary 816 mg/kg, mallard duck: 8-day dietary 1197 mg/kg). Additional toxicological studies are in progress.

In studies on its hydrostability, photostability and thermostability, SAN 619 F behaved very favourably indicating no loss of active ingredient upon storage in dilute aqueous solution of pH 5 to 9 and under UV light. SAN 619 F is extensively metabolized and slowly excreted in the rat; it has low lipophilicity and is not expected to bioaccumulate. In plants, SAN 619 F dissipates fairly rapidly; the residues of the parent compound in cereals, following two applications per season is in the range of 0.03 mg/kg. In soil, SAN 619 F is fairly stable and not very mobile with a low leaching potential. Litter degradation is retarded with SAN 619 F in the same order as with other triazoles.

BIOCHEMICAL MODE OF ACTION

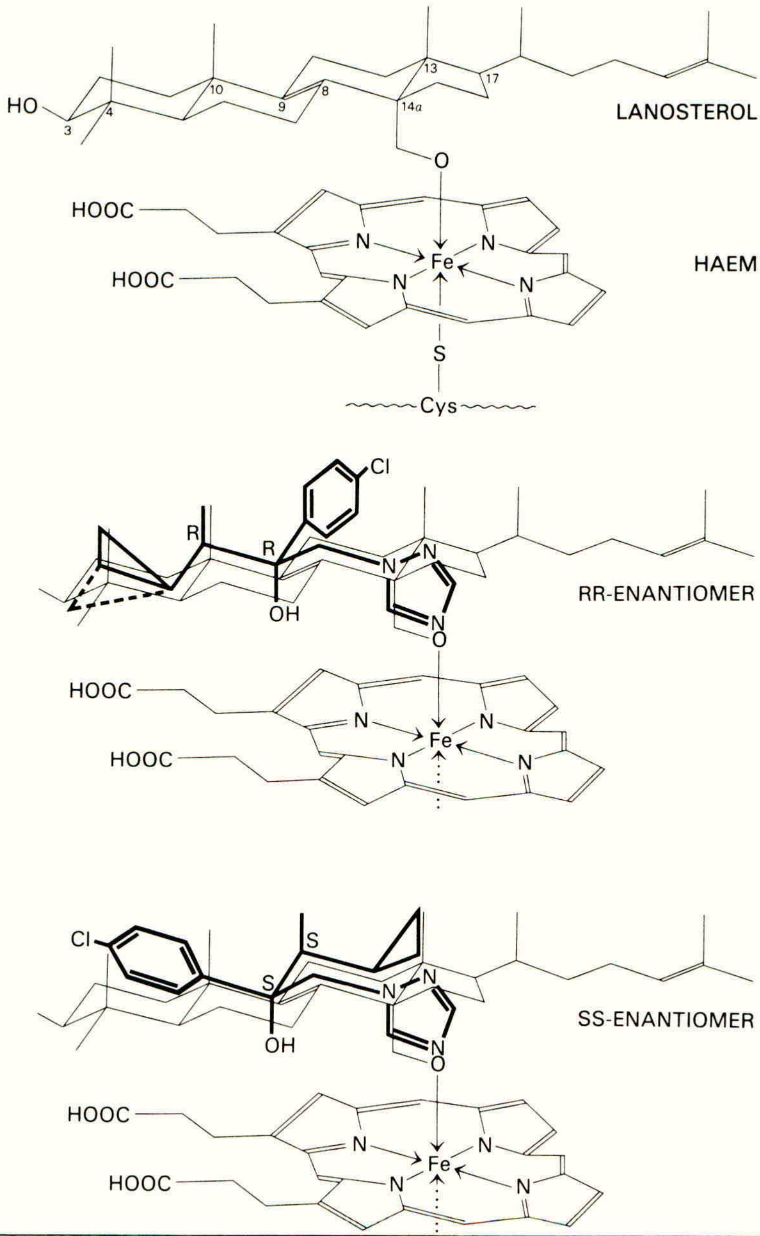
Like other triazole fungicides, SAN 619 F inhibits C-14 demethylation of sterol biosynthesis (DMI) in fungi using cytochrome P-450 enzymes for demethylation. However, SAN 619 F differs significantly in its biological behavior, spectrum and level of activity from other triazoles (Gisi *et al.*, 1986). The following model, in which the structure of SAN 619 F (either as RR- or as SS-enantiomer) is superimposed on the structure of lanosterol (Fig. 1), demonstrates the binding of lanosterol and both enantiomers of SAN 619 F to the haem part of cytochrome P-450 enzyme. The similarity in the shape of both SAN 619 F enantiomers and lanosterol probably accounts for the higher binding activity and therefore higher fungicidal activity and improved spectrum of SAN 619 F compared to other triazoles. In contrast to other triazole molecules, all four isomers of SAN 619 F show very high and more or less equal fungicide activity.

BIOLOGICAL PROPERTIES UNDER GREENHOUSE CONDITIONS

SAN 619 F shows an interesting spectrum of activity. It is very active *in vitro* and *in vivo* against most of the economically important fungi of the Asco- and Basidiomycetes, and some of the Deuteromycetes (Table 1), whereas against Zygomycetes and Oomycetes there is no activity at all (except against *Aphanomyces*: EC 90 *in vitro* = 2 mg/l) with EC 90 values higher than 100 mg/l (*in vitro*) and 900 mg/l (*in vivo*). The highest control levels were achieved against all tested powdery mildews, *Taphrina*, *Monilinia*, *Guignardia*, *Venturia*, *Mycosphaerella* (= *Cercospora*), all rusts and other Basidiomycetes like *Corticium* (= *Pellicularia*), *Fomes*, *Stereum*, *Rhizoctonia*, *Sclerotium*. Interesting levels of activity were also observed against *Cochliobolus* (= *Helminthosporium*), *Leptosphaeria* (= *Septoria*), *Sclerotinia*, *Phoma*, *Pseudocercosporella* and *Thielaviopsis*, whereas only weak activity was found against other Deuteromycetes (Table 1).

When tested under greenhouse conditions and at doses lower than 100 mg/l, SAN 619 F did not produce any symptoms of phytotoxicity on wheat, grape, apple, cucumber and other important crops. SAN 619 F is very mobile in

Figure 1 Model showing the binding of lanosterol and, superimposed to it, the RR- and SS-enantiomer of SAN 619 F to the haem part of cytochrome P-450 enzyme.



plant tissue. When the speed of penetration into bean plants, infected with Uromyces, was studied in a bioassay, SAN 619 F provided 90 % disease control after 15 min and full control after 30 min. Similar levels of control were obtained with other triazoles only after two to four hours (Gisi et al., 1986). SAN 619 F, when applied to the soil, is readily taken up by the roots and translocated to the leaves. When individual droplets of SAN 619 F were applied across the upper leaf surface, the fungicide was almost equally well

TABLE 1

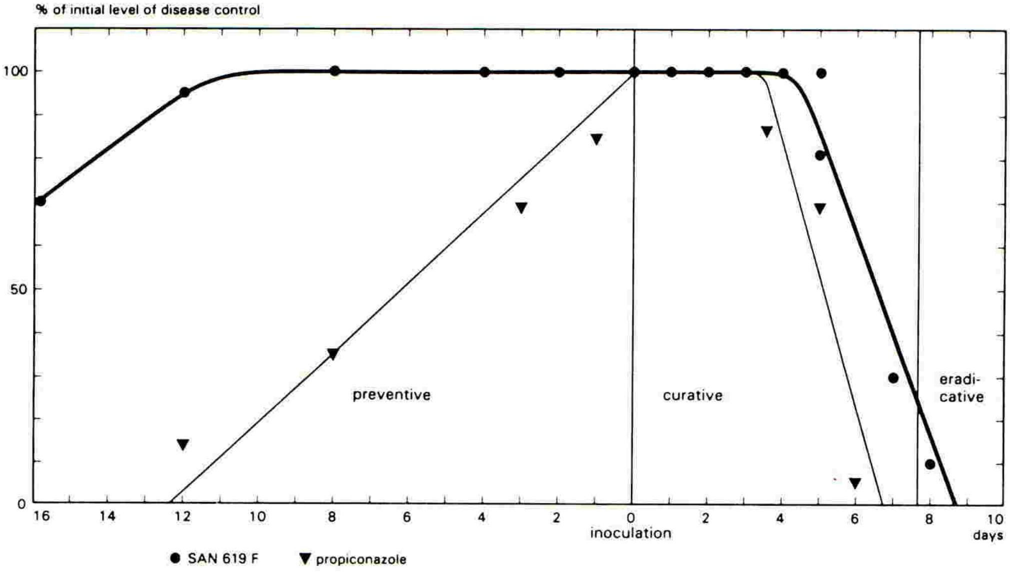
Fungicidal activity of SAN 619 F on mycelium growth of fungi (in vitro) or on plant diseases under greenhouse conditions (in vivo), expressed as EC 90 (mg a.i./l)

Fungus	SAN 619 F		propiconazole		standard (not DMI)		
	in vitro	in vivo	in vitro	in vivo	in vitro		in vivo
Ascomycetes							
Taphrina deformans	0.1	nt	0.1	nt	>100	a)	nt
Erysiphe graminis f.s. tritici	-	2	-	3	-	b)	14
Erysiphe graminis f.s. avenae	-	7	-	9	-	b)	9
Sphaerotheca fuliginea (cucumber)	-	0.6	-	0.9	-	c)	1
Uncinula necator	-	2	-	2	-	c)	5
Podosphaera leucotricha	-	2	-	2	-	c)	2
Cochliobolus (Helminthosporium) sativus	6	9	6	25	nt	d)	14
Pyrenophora graminea (slow)	30	130	2	23	>100	e)	nt
Pyrenophora graminea (fast)	4	nt	1	nt	>100	e)	nt
Pyrenophora tritici-repentis	18	nt	2	nt	>100	e)	nt
Leptosphaeria (Septoria) nodorum	2	10	2	8	nt	d)	8
Monilinia fructicola (apple)	0.1	8	0.1	13	nt	f)	200
Sclerotinia sclerotiorum	4	nt	5	nt	1	g)	nt
Guignardia bidwellii(*)	0.1	nt	nt	nt	0.6	h)	nt
Pleospora (Phoma) betae	4	nt	3	nt	nt	-	nt
Venturia inaequalis	nt	0.5	nt	3	nt	i)	14
Mycosphaerella (Cercospora) beticola	10	3	nt	30	nt	e)	500
Mycosphaerella (Cercospora) arachidis	3	2	nt	8	29	e)	58
Basidiomycetes							
Puccinia striiformis	-	2	-	7	-	k)	4
Puccinia triticina	-	2	-	9	-	k)	4
Puccinia graminis	-	2	-	8	-	k)	5
Puccinia pelargonii	-	4	-	11	-	k)	6
Puccinia anthirrini	-	2	-	9	-	k)	4
Uromyces appendiculatus	-	0.3	-	3	-	k)	13
Hemileia vastatrix	-	2	-	8	-	k)	4
Ustilago maydis	0.4	nt	0.3	nt	1	l)	nt
Corticium (Pellicularia) sasakii (rice)	10	12	47	70	1	m)	8
Fomes (Heterobasidion) annosus	0.04	nt	0.08	nt	0.2	n)	nt
Stereum purpureum	8	nt	31	nt	13	n)	nt
Rhizoctonia solani (cotton)	7	60	>100	>900	3	m)	80
Rhizoctonia (Ceratobasidium) solani	13	nt	>100	nt	>100	m)	nt
Rhizoctonia cerealis	0.9	nt	65	nt	>100	m)	nt
Sclerotium rolfsii	0.5	nt	10	nt	>100	m)	nt
Deuteromycetes							
Alternaria brassicicola (brassica)	65	15	62	35	nt	f)	20
Alternaria solani (tomato)	3	200	6	290	nt	g)	120
Botrytis cinerea (bean)	62	141	>100	>900	0.5	g)	45
Pseudocercosporella herpotrichoides	3	35	4	40	nt	g)	26
Pyricularia oryzae	10	16	23	17	28	g)	5
Thielaviopsis basicola	0.3	nt	0.2	nt	<0.01	g)	nt
Verticillium albo-atrum	>100	nt	>100	nt	10	g)	nt
Fusarium oxysporum f.s. lycopersici	>100	>900	>100	>900	nt	g)	17
Fusarium culmorum	22	nt	4	nt	4	g)	nt
Fusarium (Gibberella) avenaceum	69	nt	45	nt	nt	g)	nt
Colletotrichum coffearum	>100	nt	6	nt	85	g)	nt
Colletotrichum lindemuthianum	70	nt	10	nt	19	g)	nt
Colletotrichum lagenarium (cucumber)	>100	40	7	7	<0.1	g)	2

* results provided by INRA Bordeaux; nt = not tested; - = not applicable. Standards are: a) dithianon, b) fenpropimorph, c) bupirimate, d) guazatine, e) chlorothalonil, f) iprodion, g) benomyl, h) fenarimol, i) captan, k) oxycarboxin, l) carboxin, m) pencycuron, n) tridemorph

distributed within the leaf in all directions (acropetal, basipetal, translaminar). In another test, there was also strong transport of SAN 619 F from treated buds or stem parts into the leaves, but only acropetally, whereas there was no significant export out of treated into untreated leaves in any direction. Similar but less pronounced results were also found for other triazole fungicides (Gisi et al. 1986). The duration of preventive and curative activity of SAN 619 F (at 8 mg/l) was tested on model systems using powdery mildews (Sphaerotheca on cucumber or Uncinula on grapes) and rusts (Uromyces on bean or Puccinia on snap dragon). SAN 619 F completely controlled powdery mildew and, especially, rust diseases under greenhouse conditions for at least 12 to 14 days when used preventively and about 4 to 6 days when used curatively (which is almost the entire incubation time). The results with SAN 619 F against Puccinia (Fig. 2) compare very favourably with standard materials which are generally shorter in duration of activity (Gisi et al., 1986). Interesting levels of fungicidal activity of SAN 619 F were also found when the fungicide was used eradicatively, although the molecule was not as active in this disease stage as it was during the curative stage.

Figure 2 Overall duration of fungicidal activity of SAN 619F and propiconazole (at 8 mg/l) against *Puccinia*/snap dragon under greenhouse conditions. One application was made either x days before inoculation (preventive), or x days after inoculation (curative and eradicative).



BIOLOGICAL PROPERTIES UNDER FIELD CONDITIONS

More than 1300 field trials were conducted from 1983 to 1986 in several crops against different diseases throughout the world.

CEREALS

SAN 619 F was evaluated worldwide for control of brown rust (Puccinia triticina) and yellow rust (P. striiformis) in wheat and P. hordei in barley. Doses as low as 60 to 80 g a.i./ha provided excellent control for a period of 4 to 6 weeks with an average efficacy range of 90-95 %. As illustrated in Table 2, the 60 and 80 g a.i./ha doses of SAN 619 F were superior to the standards propiconazole at 125 g a.i./ha and fenpropimorph at 750 g a.i./ha. Rust control was clearly indicated as a major advantage for SAN 619 F over the standards. The very good activity of SAN 619 F at doses of 60 to 80 g a.i./ha was demonstrated on powdery mildew (Erysiphe graminis) in wheat and barley for a period of at least 3 to 4 weeks. As shown in Table 2, SAN 619 F at 80 g a.i./ha tended to be more effective than propiconazole in wheat and practically equal to fenpropimorph. In barley, SAN 619 F at 80 g a.i./ha provided an average of 85 % control, which was approximately equal to the control obtained by propiconazole at 125 g a.i./ha and fenpropimorph at 750 g a.i./ha. Under cool weather conditions, particularly during the application period in spring and early summer, the addition of a morpholine to SAN 619 F increased the control of powdery mildew.

TABLE 2

Control of rusts (Puccinia spp.) and powdery mildews (Erysiphe graminis) of cereals in France and Switzerland

Treatment	Dose	Mean. % control			
	(g a.i./ha)	rust		powdery mildew	
		2-3 weeks	4-6 weeks	wheat	barley
SAN 619 F	60	90	88	81	76
SAN 619 F	80	93	93	90	85
Propiconazole	125	73	65	85	85
Fenpropimorph	750	79	70	88	89
Nos. of trials		35	20	75	15

SAN 619 F at doses of 80 to 120 g a.i./ha provided 35-45 % control of eyespot (Pseudocercosporella herpotrichoides) in wheat and barley while the standard prochloraz applied at 480 g a.i./ha gave an average control of 66 %. A combination of SAN 619 F + prochloraz at 80 + 300 g a.i./ha gave an average of 62 % control and yield increases equal to the standard. This combination has interesting potential for both eyespot control and early powdery mildew control. In a limited number of trials, SAN 619 F at 80-100 g a.i./ha provided suppression of sharp eyespot (Rhizoctonia cerealis).

With a single application against leaf blotch (Septoria spp.) and glume blotch (Septoria nodorum) in wheat the dose response of SAN 619 F was not as pronounced as against rust or powdery mildew; SAN 619 F at 80 g a.i./ha provided a suppression of approximately 40-50 %. The addition of a partner fungicide, such as chlorothalonil or prochloraz increased control levels to the 75 % range which was equal to the best standards.

The dose response of SAN 619 F against leaf blotch (Rhynchosporium secalis) in barley was not pronounced with 60 to 80 g a.i./ha providing 65-70 % control. The addition of reduced doses of prochloraz or chlorothalonil provided approximately 80 and 90 % control, respectively. At doses of 60 to 100 g a.i./ha, SAN 619 F provided control of net blotch (Pyrenophora teres) in barley in the 40-50 % range as compared to the 60 % range with propiconazole and prochloraz. The control levels obtained with the combination of SAN 619 F + prochloraz at 80 + 300 g a.i./ha was equal to the best standard treatments.

Generally, SAN 619 F was well tolerated by wheat and barley under a wide range of conditions. In a few trials against foot diseases, SAN 619 F, applied early in the season (first knot stage), caused some slight stunting (PGR effect). However, no negative influence on yield was observed in any of the trials.

GRAPES

Extensive field work in France, Switzerland, Italy and Portugal demonstrated that SAN 619 F, applied at 1.0 g a.i./hl, at 2-3 week intervals, controlled powdery mildew (Uncinula necator) very effectively (Table 3). This dose of SAN 619 F was at least as effective as the best standard products in controlling powdery mildew on leaves and bunches. Additional activity on black rot, (Guignardia bidwelli), was also observed and will be further investigated. Crop safety was generally good at the effective dose tested.

TABLE 3

Control of powdery mildew (Uncinula necator) on grape leaves and bunches in Switzerland, France, Italy, Portugal and Spain

Treatment	Dose	Mean. % control	
	(g a.i./ha)	leaves	bunches
SAN 619 F	1.0	93	96
SAN 619 F	1.2	92	95
Fenarimol	3.6	92	95
Triadimefon	5.0	93	96
Nos. of trials		26	26

APPLES

Field evaluations in apples were conducted mainly in Switzerland, France and Italy. When applied on a 14 day schedule, SAN 619 F at 1.0 to 1.2 g a.i./hl provided good control of powdery mildew (Podosphaera leucotricha) and scab (Venturia inaequalis). This activity was similar on leaf and fruit infections and was equal to the standard fenarimol (Table 4). The addition of products such as captan and dithianon improved the scab performance of SAN 619 F, especially in cases of severe disease pressure. In most trials crop safety at the effective dose was acceptable. Like other fungicides in the triazole class, SAN 619 F causes occasional PGR-effects, which occur mainly from early season applications under cold weather conditions.

TABLE 4

Control of apple scab (Venturia inaequalis) and powdery mildew (Podosphaera leucotricha) on apples in France, Italy and Switzerland

Treatment	Dose	Mean. % control		
	(g a.i./ha)	scab		powdery mildew
		leaves	fruit	leaves
SAN 619 F	1.0	88	95	83
SAN 619 F	1.2	90	96	90
Fenarimol	3.6	91	95	93
Nos. of trials		42	47	16

SUGAR BEET

The efficacy of SAN 619 F on the leaf spot diseases of sugar beet, (Cercospora beticola and Ramularia beticola) was excellent at doses as low as 40 to 60 g a.i./ha, and was superior to the best standards (Table 5). In trials conducted against sugar beet rust (Uromyces betae) excellent control, superior to the standards, was obtained at doses of 40 to 60 g a.i./ha.

TABLE 5

Control of Cercospora beticola, Ramularia beticola and Uromyces betae in sugar beet in Switzerland and Italy; (TPTA = Fentinacetate)

Treatment	Dose (g a.i./ha)	Mean. % control			% sugar increase
		C. beticola	R. beticola	U. betae	
SAN 619 F	40	82	90	95	13
SAN 619 F	60	87	93	96	19
SAN 619 F+TPTA	60+180	89	94	96	21
Propiconazole+TPTA	156+225	79	nt	nt	17
TPTA	360	69	49	48	10
Nos. of trials		9	2	2	3

PEANUTS

Trials in the United States and India with SAN 619 F for the control of early and late leaf spot diseases (Cercospora arachidicola and Cercosporidium personatum) indicated that applications of SAN 619 F at 37 to 100 g a.i./ha, resulted in better disease control than standard fungicides. As illustrated in Table 6, the high levels of leaf spot and white mold (Sclerotium rolfsii) control resulted in significant yield increases when compared to the standard treatment. Rhizoctonia control was also observed in the same trials.

TABLE 6

Control of early and late leaf spot (Cercospora arachidicola and Cercosporidium personatum) and white mold (Sclerotium rolfsii) in peanuts in the USA

Treatment	Dose (g a.i./ha)	Appl. interval (weeks)	Mean. % control		% yield increase relative to standard
			leaf spot	white mold	
SAN 619 F	37	2	92	85	16
SAN 619 F	62	2	92	92	41
SAN 619 F	62	3	85	83	19
SAN 619 F	100	2	97	94	31
Chlorothalonil	1400	2	98	75	-
Nos. of trials			5	2	1

REFERENCES

Gisi,U., Rimbach,E., Binder,H., Altwegg,P., Hugelshofer,U. (1986). Biological profile of SAN 619 F and related EBI-fungicides. Proceedings 1986 British Crop Protection Conference - Pests and Diseases.

BAY HWG 1608, A NEW FUNGICIDE FOR FOLIAR SPRAY AND SEED-TREATMENT USE AGAINST A WIDE SPECTRUM OF FUNGAL PATHOGENS

P. Reinecke, H. Kaspers, H. Scheinpflug, G. Holmwood

Bayer AG, Agrochemicals Division, Biological Research, Biological Development, Chemical Research, D-5090 Leverkusen, Bayerwerk, West-Germany

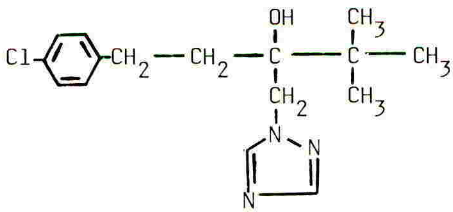
ABSTRACT

BAY HWG 1608 is highly effective as a seed treatment (Raxil(R)) or as a foliar fungicide (Folicur(R)) on several economically important crops. On cereals the seed treatment controls smut (*Ustilago* spp.), bunt (*Tilletia* spp.) and other seedborne diseases like *Septoria*; foliar sprays are active against leaf and head diseases including *Fusarium*, *Septoria*, *Pyrenophora*, *Cochliobolus*, rusts and powdery mildew. The broad fungicidal spectrum of the compound usually results in high yield increases. BAY HWG 1608 is also effective against *Mycosphaerella* on bananas and against important grape pathogens, including *Botrytis cinerea*. Furthermore the compound can be successfully applied in a wide range of crops, like peanuts, soybeans, rape, tea and several vegetables.

TECHNICAL DATA

Chemical name: (*RS*)-1-(4-chlorophenyl)-4,4-dimethyl-3-(1*H*-1,2,4-triazol-1-ylmethyl)pentan-3-ol

Structural formula:



Molecular formula:	$C_{16}H_{12}ClN_3O$
Molecular weight:	307,81
Appearance:	colourless crystals
Melting point:	104,7° C
Solubility:	water 32 mg/l
	good solubility in different organic solvents

MAMMALIAN TOXICITY

Acute oral LD_{50}:	rat (male)	> 5000 mg/kg
	rat (female)	3933 mg/kg
Acute dermal LD_{50}:	rat (male)	> 5000 mg/kg
	rat (female)	> 5000 mg/kg
Irritation:	not irritating to skin or eye (rabbit)	
Mutagenicity:	negative (*E. coli*, *Salmonella*)	
Embryotoxicity:	negative (rabbit)	
Bird toxicity:	canary LD_{50}	> 1000 mg/kg
	hen LD_{50}	4488 mg/kg

FORMULATIONS

This fungicide will be marketed under the tradename RAXIL(R) as a seed dressing and as FOLICUR(R) for spray application. RAXIL(R) will be available as a powder formulation for dry seed treatment (DS), as a water-dispersible powder for slurry treatment (WS) and as a flowable concentrate (FS), in order to cater for all the seed treatment methods used in practice. FOLICUR(R) is formulated as a water-dispersible powder (WP), an emulsifiable concentrate (EC) and an emulsion in water (EW).

CEREAL SEED TREATMENT

In several years of field trials BAY HWG 1608 gave excellent control of seed-borne smuts and bunts in wheat, barley, rye, oats and corn. The effective doses are extremely low, 2 to 3 g a.i./dt seed resulted in complete suppression of *Ustilago nuda*, *U. avenae*, *Tilletia caries* and *T. foetida*. This amount also controls seed-borne *Leptosphaeria nodorum* (Table 1).

TABLE 1

Effective doses (g a.i./dt) of BAY HWG 1608 against seed-borne diseases of cereals

Pathogen	BAY HWG 1608	Standard product
WHEAT		
Ustilago nuda	2,5	= triadimenol 15
Tilletia caries } *Tilletia foetida* }	3	= triadimenol 15 - 22,5
Leptosphaeria nodorum	3	≧ triadimenol 37,5
Cochliobolus sativus	25	> triadimenol 37,5
Puccinia recondita	25	≧ triadimenol 37,5
BARLEY		
Ustilago nuda	2	= triadimenol 15
Pyrenophora graminea	10	≧ triadimenol 37,5
OATS		
Ustilago avenae	2	≧ triadimenol 15
CORN		
Sphacelotheca reiliana	25	= triadimenol 60

Higher dosages (25 g a.i./dt seed) control other seed-borne diseases such as *Cochliobolus sativus* on wheat and *Sphacelotheca reiliana* on corn. Moreover, *Puccinia recondita* (leaf rust of wheat) is suppressed for several weeks after emergence, resulting in a significant delay in the build-up of an epidemic. 10 g a.i./dt seed are needed for control of barley stripe disease (*Pyrenophora graminea*).

It should be mentioned, however, that more than 5 g a.i./dt seed of BAY HWG 1608 may lead to reduced emergence under cold weather conditions. But in warmer regions 25 g a.i./dt seed seem to be well tolerated.

CEREAL LEAF AND EAR SPRAY APPLICATION

BAY HWG 1608 controls a wide range of diseases in cereals (Table 2). Spraying in cereals gives outstanding control of all rust diseases (leaf rust, stem rust, stripe rust) and is clearly better than triadimefon or other standards (Table 3).

TABLE 2

Effective doses (g a.i./ha) of BAY HWG 1608 against leaf and ear diseases of cereals

Pathogen	BAY HWG 1608	Standard product
WHEAT		
Puccinia recondita *Puccinia graminis* *Puccinia striiformis*	125	> triadimenol 125
Erysiphe graminis	250	= triadimenol 125
Mycosphaerella graminicola	250	> triadimenol 250
Cochliobolus sativus	250	≫ propiconazole 125
Pyrenophora tritici-repentis	250	> propiconazole 125
Leptosphaeria nodorum	250	≥ captafol 1600
Fusarium spp.	375	> captafol 1600
BARLEY		
Puccinia hordei *Puccinia striiformis*	125	> triadimenol 125
Rhynchosporium secalis	250	> triadimenol 125
Pyrenophora teres	250	≫ propiconazole 125
Cochliobolus sativus	250	≫ propiconazole 125
Erysiphe graminis	250	= triadimenol 125

TABLE 3

Mean % control (Abbott) (and range) of *Puccinia recondita* on wheat by BAY HWG 1608

Year	BAY HWG 1608					triadimenol (g a.i./ha)	untreated control % disease	Nos. of trials
	25 WP (g a.i./ha)			250 EC (g a.i./ha)				
	125	250	500	125	250	125		
1982	67 (40-96)	86 (85-86)				52 (30-98)	88	3
1983	66 (50-97)			72 (53-99)		69 (48-98)	44 (12-58)	5
			95 (83-100)			84 (63-98)	39 (12-100)	7
1984				96 (89-100)	99 (98-100)	91 (70-97)	49 (8-63)	5

Apart from rust and powdery mildew, leaf diseases including Pyrenophora spp. (Table 4), Cochliobolus spp. and, especially, Septoria spp. (Leptosphaeria nodorum and Mycosphaerella graminicola), are eliminated to a greater extent than with 1600 g a.i./ha of captafol or mancozeb (Table 5). Furthermore, BAY HWG 1608 also gives good control of Fusarium ear scab.

TABLE 4

Mean % control (Abbott) (and range) of Pyrenophora teres on barley by BAY HWG 1608 in 1985

BAY HWG 1608			propiconazole	untreated control	Nos. of trials
125 EW (g a.i./ha)		250 EC (g a.i./ha)	250 EC (g a.i./ha)		
250	375	250	125		
78 (70-88)	88 (84-93)	74 (65-83)	82 (75-88)	32 (17-46)	4 Germany
71 (30-85)		71 (36-89)	74 (40-86)	75 (40-86)	5 Brazil

TABLE 5

Mean % control (Abbott) (and range) of Leptosphaeria nodorum on wheat by BAY HWG 1608 in 1985

Site	BAY HWG 1608			triadimefon + captafol (g a.i./ha)	untreated control % disease	Nos. of trials
	125 EW (g a.i./ha)		250 EC (g a.i./ha)			
	375	500	375	125+1300		
Leaf	66 (52-76)	69 (56-85)	66 (53-75)	66 (59-77)	55 (44-65)	3
Ear	64 (37-83)	68 (34-87)	67 (39-85)	54 (37-71)	61 (30-92)	10
Yield	112	112	112	112	-	9

These diseases, particulary rust, Septoria and Fusarium, usually cause great yield losses and the application of BAY HWG 1608 therefore results in high yield increases.

PEANUT DISEASES

BAY HWG 1608 is superior to the commercial standards, e.g. chlorothalonil, in control of the most important diseases of peanuts (Table 6).

TABLE 6

Effective doses (g a.i./ha) of BAY HWG 1608 against diseases of peanuts

Pathogen	BAY HWG 1608	Standard product
Puccinia arachidis	125	> chlorothalonil 1260
Mycosphaerella arachidis	187	> chlorothalonil 1260
Mycosphaerella berkeleyi	187	> chlorothalonil 1260

Against Mycosphaerella spp., such as M. arachidis and M. berkeleyi, an application rate of 187 g a.i./ha is sufficient. Excellent control of peanut rust, Puccinia arachidis, is achieved with as little as 125 g a.i./ha.

Experience from several years of field trials shows that in controlling these diseases in peanuts, BAY HWG 1608 provides high yield increases and improvement in quality in this important crop.

GRAPE DISEASES

Two major grape diseases all over the world are grey mould, caused by Botrytis cinerea, and powdery mildew, due to Uncinula necator. The chemical constitution of BAY HWG 1608, being a triazole derivative, implies good powdery mildew activity. In our experience 100-250 g a.i./ha of BAY HWG 1608 are as effective as 100-175 g a.i./ha triadimefon (Table 7).

TABLE 7

Effective doses (g a.i./ha) of BAY HWG 1608 against diseases of grapes

Pathogen	BAY HWG 1608	Standard product
Botrytis cinerea	500-1000	= dicarboximide 1000
Uncinula necator	100	= triadimefon 100

The broad-spectrum activity of this new compound, however, also enables the wine-grower to control grey mould with the same compound. The effective rate is 500 g a.i./ha compared to about 1000 g a.i./ha with one of the standard dicarboximide fungicides.

DISEASES OF OTHER CROPS

Apart from the crops just mentioned, there are many other potential uses of BAY HWG 1608 against major economic diseases. The following are a few examples:

Mycosphaerella fijiensis, var. difformis, the so-called "Black Sigatoka" disease, causes huge losses in banana production. At the very low dose of 75-100 g a.i./ha BAY HWG 1608 gives equivalent or better control of this disease than 1200-1800 g a.i./ha of the commercial standard.

Worldwide, Exobasidium vexans is a very serious disease in tea. Hitherto the standard control procedure is to spray copper at about 500 g a.i./ha. BAY HWG 1608 is better at 50-100 g a.i./ha.

Rape, an important oilseed crop, is subject to attack by Sclerotinia sclerotiorum in many parts of the world. BAY HWG 1608 controls this pathogen at 500-750 g a.i./ha.

Other potential uses of BAY HWG 1608 that should be mentioned very briefly are Cochliobolus miyabeanus and Pyricularia oryzae on rice, diseases of turf grass, various diseases of vegetables such as Sclerotinia cepivorum on onions, and Puccinia helianthi on sunflowers.

PYRIFENOX, A NEW PYRIDINE FUNGICIDE AGAINST FOLIAR AND FRUIT DISEASES

P. ZOBRIST, K. BOHNEN, H. SIEGLE

Dr. R. Maag AG., CH-8157 Dielsdorf, Switzerland

F. DORN

Socar AG., CH-8600 Dübendorf, Switzerland

ABSTRACT

Pyrifenox, 2',4'-dichloro-2-(3-pyridyl)acetophenone O-methyloxime, is a new fungicide with protective and curative activity. It acts against various plant pathogenic Ascomycetes, Basidiomycetes and Deuteromycetes. It has been tested in the field over a period of several years, primarily on pome fruits, grapes and groundnuts. When sprayed with 5 g a.i./hl of pyrifenox apple scab (*Venturia inaequalis*) and powdery mildew (*Podosphaera leucotricha*) were very effectively controlled. 37.5 - 50 g a.i./ha were needed to combat grape powdery mildew (*Uncinula necator*). Against early leaf spot (*Cercospora arachidicola*) and late leaf spot (*Cercosporidium personatum*) on groundnuts 70 - 140 g a.i./ha of pyrifenox were required. Crop tolerance is excellent. On the basis of its biological properties and environmental behaviour pyrifenox is a very suitable fungicide for modern integrated disease management.

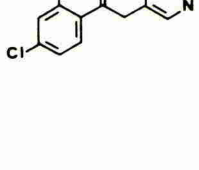
INTRODUCTION

Pyrifenox is a new agrofungicide discovered in the research laboratories of Dr. R. Maag Ltd. Extensive field evaluation as well as studies on toxicology and environmental behaviour have been carried out since 1980. Pyrifenox was first introduced for practical use in Switzerland in 1986. The object of this paper is to characterise this fungicide.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name (IUPAC): 2',4'-dichloro-2-(3-pyridyl)acetophenone O-methyloxime

Structure:



Molecular formula:	$C_{14}H_{12}Cl_2N_2O$
Code number:	Ro 15-1297
Common name:	pyrifenox
Molecular weight:	295.17
Density (20°C):	1.28 kg/l
Boiling point:	>150°C at 0.1 mm Hg
Vapour pressure (25°C):	1.9 mPa (1.4 x 10^{-5} torr)
Solubility (20°C):	in water: 115 mg/l at pH 7; soluble in common organic solvents (>250 g/l in acetone, ethyl acetate, chloroform, diethyl ether, dimethylformamide, isopropyl alcohol and toluene); slightly soluble in hexane (<1 g/l).
Form:	slightly viscous liquid, tan in colour with a mild aromatic odour.
Stability:	stable at room temperature, to UV light and to hydrolysis in water at pH 3, 7 and 9.

FORMULATION

For practical application pyrifenox can for example be formulated as a wettable powder (WP) or as an emulsifiable concentrate (EC). Other types of formulation are being studied.

TOXICOLOGY

Acute toxicity:	LD_{50} oral rat	:	2900	mg/kg
	LD_{50} dermal rat	:	>5000	mg/kg
	LD_{50} intraperitoneal rat	:	950	mg/kg
	LC_{50} inhalation rat	:	>2.05	mg/l
Skin and eye irritation:	Slight irritant of skin (guinea pig) and of eye (rabbit); no skin sensitizing potential (guinea pig)			
Mutagenicity:	No mutagenic potential			
Teratogenicity:	No teratogenicity or embryotoxic effects			

WILD LIFE HAZARD STUDIES

Birds:	LD_{50} oral	mallard duck	: >2000 mg/kg
		bobwhite quail	: >2000 mg/kg
Aquatic organisms:	LC_{50} (96 hours)	rainbow trout	: 7.1 mg/l
		miror carp	: 12.2 mg/l
		bluegill sunfish	: 6.6 mg/l
	EC_{50} (48 hours)	daphnia	: 3.6 mg/l
Honey bees:	LD_{50} oral	(48 hours)	: 59 µg/bee
	LD_{50} contact	(48 hours)	: 70 µg/bee

It may be concluded from toxicity data available on birds, aquatic organisms and honeybees that pyrifenox is of low order toxicity.

ENVIRONMENTAL CHEMISTRY

Soil: Extensive degradation of pyrifenox was proved by $^{14}CO_2$ production. The active ingredient and its metabolites showed little or no tendency to leach in a soil column test.

Animals: Rapid metabolism and elimination occured in rat through urine and faeces after oral uptake. There are no indications of bioretention. The bioaccummulation factor in channel catfish in a static system was small. Depuration was over 90% within 10 days.

Plants: Metabolism studies showed a relatively rapid degradation of pyrifenox in plants. A half-life of 4 days was determined in peanut leaves. For degradation in apple leaves and fruit half-lifes obtained were 3 and 9 days respectively.

BIOLOGICAL PROPERTIES

Pyrifenox is a broad spectrum fungicide which prevents growth *in vitro* and *in vivo* of a wide range of Ascomycetes, Basidiomycetes and Deuteromycetes. At low rates (30-250 g a.i./ha) it has strong curative and protective activity. The persistence of the protective activity is shorter than that of common residual fungicides. After foliar application there is a rapid penetration into the leaves. Rain after 1 to 3 hours does not further affect the activity of pyrifenox. With seed and root application pyrifenox was shown to be systemic. There is acropetal transport of the active ingredient in xylem vessels.

The plant tolerance of pyrifenox is very good. At the recommended dosages no limitations of use against target diseases due to inadequate plant compatibility are known so far.

In biochemical studies pyrifenox was found to be an ergosterol biosynthesis inhibitor, strongly blocking 14α-demethylation (Masner & Kerkenaar, in preparation).

FIELD TRIALS

Several years of field work with pyrifenox have confirmed its field performance on economically important crops and pathogens. The trials presented have been selected to show typical disease control levels generally achieved under uniform and intense conditions of fungal infestation.

Top fruit

Pyrifenox provided excellent control of apple scab and powdery mildew (Table 1). The compound was formulated as a 25% WP and applied in a protectant spray programme starting at green tip of the fruit. Fenarimol was used as the commercial formulation with 120 g/l EC. Curative treatments for scab control with pyrifenox are feasible where a scab forecasting system is available. In contrast to common residual fungicides a fixed spray schedule is no longer necessary. Treatments can be restricted to the cases where climatic conditions for infection have been fulfilled. The spray application however has to be made within 96 h of the beginning of an infection period.

TABLE 1

Control of apple scab (*Venturia inaequalis*) and powdery mildew (*Podosphaera leucotricha*)

Treatment	Dose (g a.i. / hl)	% leaf scab[a]	% fruit scab[a]	% leaf mildew[a]
		(7 trials, Switzerland)		
Untreated	-	72.2	62.1	62.7
Fenarimol	3.6/2.4[b]	3.5	4.1	6.8
Pyrifenox	5	2.3	3.7	3.1

a = after 8 to 11 applications at 10 to 14 day intervals
b = before / after bloom

No phytotoxic or adverse effects on the weight, shape or size of foliage or fruit were observed.

The degree of blossom and twig blight as well as powdery mildew control on stone fruit (Tables 2 and 3) achieved with pyrifenox was better than results obtained with respective standard compounds. Pyrifenox was applied as a 25% WP or a 250 g/l EC formulation in these trials. The standard fungicides were used in the form of the commercial products: iprodione as 50% WP and fenarimol with 120 g/l EC.

TABLE 2

Control of blossom and twig blight (Monilia laxa) on apricots

Treatment	Dose (g a.i. /hl)	% infected twigs[a] (4 trials, Switzerland)
Untreated	-	26.0
Iprodione	50	11.5
Pyrifenox	5	6.4

a = after 2 applications (beginning of flowering and full bloom)

TABLE 3

Efficacy against powdery mildew (Sphaerotheca pannosa) on peaches

Treatment	Dose (g a.i. /hl)	% mildew on leaves[a] (4 trials, Spain)
Untreated	-	14.8
Fenarimol	3.96	8.3
Pyrifenox	7.5	3.8
Pyrifenox	5	6.0

a = after 4 to 5 applications

Grape vines

Preventive spray programmes with pyrifenox revealed efficient control of powdery mildew on grape vines (Table 4). The treatments were made with a 250 g/l EC formulation, starting at the first fully expanded leaf stage. Fenarimol was applied as the commercial product with 40 g/l EC.

TABLE 4

Activity of pyrifenox against powdery mildew (Uncinula necator) on grapes in comparison to a standard fungicide

Treatment	Dose (g a.i. /ha)	% mildew on leaves[a]	% mildew on bunches[a]
		(4 trials, France)	
Untreated	-	18.3	45.1
Fenarimol	18	0.6	1.9
Pyrifenox	50	0.3	0.7
Pyrifenox	37.5	0.7	1.4

a = after 6 to 8 applications at 14 day intervals

Phytotoxic effects were not observed at the doses tested, nor was any effect on fermentation or vine quality noted.

Partial control of black rot (Guignardia bidwellii) has been recorded in several field trials.

Peanuts

The application of 70 to 140 g of pyrifenox/ha in a 14 day schedule resulted in better control of early and late leaf spot than the standard under conditions of moderate to severe disease incidence (Table 5). No phytotoxicity was observed. The candidate compound was evaluated as a 480 g a.i./l EC formulation. The standards were applied as commercial formulations: chlorothalonil with 500 g/l SC and mancozeb as 80% WP.

TABLE 5

Control of early (Cercospora arachidicola) and late leaf spot (Cercosporidium personatum) on peanuts

Treatment	Dose (g a.i. /ha)	% leaf spot[a] (5 trials, Southeast USA)	% defoliation[a] (5 trials, Southeast USA)	Numbers of lesions per leaf[b] (1 trial, Australia)	% defoliation[b] (1 trial, Australia)
Untreated	-	10.4	82.0	19.3	80.0
Chlorothalonil	1250	2.5	17.4	-	-
Mancozeb	1360	-	-	4.0	38.8
Pyrifenox	140	0.5	6.2	1.5	6.3
Pyrifenox	70	0.7	11.1	2.3	12.3

a = after 6 to 7 applications at 14 day intervals
b = after 3 applications at 14 day intervals

CONCLUSIONS

1. Pyrifenox is a suitable fungicide for the control of economically important diseases of fruit trees, grapes and groundnuts on the basis of its spectrum of activity, high efficacy at low dosages, protective activity, strong curative properties and good crop tolerance. Excellent disease control can be achieved under varied climatic conditions.

2. The spectrum of antifungal activity of pyrifenox suggests possibilities for additional fields of application against fungal diseases on field crops, vegetables and ornamental plants. For some crops with specific requirements, pyrifenox can also be combined with other fungicides offering complementary properties (e.g. to complete the spectrum of activity or to provide longer protective activity).

3. The target selectivity, biological properties, toxicology and environmental chemistry of pyrifenox fulfil the requirements of integrated plant protection and guarantee minimal environmental impact.

REFERENCES

Masner P., Kerkenaar A. (in preparation) Effect of the pyridine fungicide pyrifenox on sterol biosynthesis in Ustilago maydis.

MYCLOBUTANIL, A BROAD-SPECTRUM SYSTEMIC FUNGICIDE FOR USE ON FRUIT, VINES AND A WIDE RANGE OF OTHER CROPS

C.ORPIN, A.BAUER, R.BIERI, J.M.FAUGERON, G.SIDDI

ROHM AND HAAS COMPANY, EUROPEAN OPERATIONS, CHESTERFIELD HOUSE, BLOOMSBURY WAY, LONDON, WC1A 2TP

ABSTRACT

Myclobutanil, 2-(4-chlorophenyl)-2-(1H-1,2,4-triazol,-1-ylmethyl)hexanenitrile, is a new ergosterol-biosynthesis inhibiting fungicide with curative and protectant properties. The fungicide is particularly effective against fungi in the subclass Loculoascothycetidae and against powdery mildew and rusts.

Field trials have demonstrated excellent activity on apple powdery mildew (Podosphaera leucotricha), apple scab (Venturia inaequalis), vine powdery mildew (Uncinula necator) and vine black rot (Guignardia bidwellii). Results of laboratory, greenhouse and field tests indicate that myclobutanil is systemic and has curative activity against scab for 96-120 h.

Results on control of the diseases of cereal seeds, sugar beet, stone fruit, roses and cucurbits are promising but require futher work to clearly define effective doses and timings of applications.

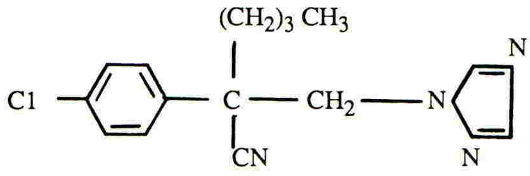
Trials in a wide range of geographic and climatic conditions have shown that, at doses required for effective disease control, myclobutanil has no phytotoxic effects on the treated crop.

INTRODUCTION

Myclobutanil is a new systemic triazole fungicide discovered and patented by Rohm and Haas Company. This paper describes the properties of the fungicide and its performance on various diseases of apples, vines and other crops.

TECHNICAL DATA

Structural formula :



Molecular formula : $C_{15}H_{17}C1N_4$

Code number : RH-3866

Systemic chemical name : 2-(4-chlorophenyl)-2-(1H-1,2,4-triazol,-1-ylmethyl)hexanenitrile

Common name : myclobutanil

Trade names and formulations include : SYSTHANE 40W (400 g a.i./kg)
SYSTHANE 12EC (125 g a.i./litre)
SYSTHANE 6FLO (60 g a.i./litre)

Appearance : Light yellow crystals

Melting point : 63-68°C

Solubility : 0.142 g/l at 25°C in water; soluble in most organic solvents at 50-100 g/l

Vapour pressure : 1.6 x 10^{-6} torr/25°C

TOXICOLOGY

Acute Oral LD_{50} : Rat (male) 1600 mg/kg
Rat (female) 2229 mg/kg

Acute Dermal LD_{50} : Rabbit 7500 mg/kg

Sensitization : Non-sensitizing
Irritation : Non-irritating
Mutagenicity : Negative

Long-term studies are nearly complete and provisional registrations have been obtained in France for use of the fungicide on vines and the UK for its use on apples and pears.

BIOLOGICAL PROPERTIES

Myclobutanil is chemically related to the ergosterol-biosynthesis inhibitor (EBI) family of fungicides. Myclobutanil is particularly effective against fungi in the subclass Loculoascomycetidae and against powdery mildews and rusts, exhibiting both protective and curative activity against these diseases. Myclobutanil has no activity against Oomycetes.

METHODS AND MATERIALS

Myclobutanil has been tested alone and in tank mixtures with several other fungicides against a wide range of pathogens on different crops throughout Europe. All treatments in trials were replicated 3-4 times and arranged in randomised block designs. The plot size for apples and other tree crops was 3-4 trees and for vines 10-15 plants. Applications of fungicides were made using a knapsack sprayer and water volumes of 1500-2000/ha for apples and other tree fruits and 200-1000/ha for vines were applied.

Assessment methods for efficacy and crop tolerance were based on nationally accepted guidelines and usually involved counting the infected leaves or fruit and estimating disease or damage relative to either an untreated or standard control.

Spray application schedules were initiated either at the onset of disease incidence or were based on plant development according to local recommendations.

The results presented are representative of a large number of trials througout Europe; the selected trials had uniform and heavy disease pressures.

RESULTS AND DISCUSSION

APPLES AND PEARS

Myclobutanil has been tested at doses of 3.0-6.0 g a.i./hl on a 7-14 day preventative spray schedule for the control of apple scab (V.inaequalis) (Table 1). Excellent control of fruit and leaf infections has been achieved with myclobutanil at 6.0 g a.i./hl in trials throughout Europe.

TABLE 1

Control of V.inaequalis on apples (cv Golden Delicious), at Poggio Renatico (FE), Italy, in 1984.

Treatment	Dose (g a.i./100 l)	% infected	
		Leaves	Fruit
Myclobutanil	3.0	10.6	17.8
Myclobutanil	4.5	6.0	9.0
Myclobutanil	6.0	2.7	4.0
Fenarimol + mancozeb	4.5 + 120	11.1	14.0
Untreated		55.9	100.0
LSD P = 0.01		3.6	5.6

At 4.5 g a.i./hl, myclobutanil also gave good control of apple scab. However, under severe disease pressure, control of fruit scab was enhanced by mixtures with low rates of either mancozeb (120 g a.i./hl) or captan (50 g a.i./hl). Results were similar for pear scab (Venturia pirina).

Where mildew is absent a lower dose of 3.5 g a.i./hl of myclobutanil with mancozeb at 120 g a.i./hl gives good control of apple scab. (Table 2)

TABLE 2

Control of V.inaequalis on apples (cv Starkrimson), at Gorzano, Italy, in 1984 with 10 sprays on a 7-14 day preventative schedule.

Treatment	Dose (g a.i./100 l)	% infected Leaves	% infected Fruit
Myclobutanil	3	6.2	9.7
Myclobutanil	4.5	1.2	5.5
Bitertanol	18.75	7.2	3.5
Myclobutanil + mancozeb	3.5 + 120	1.0	2.0
Fenarimol + mancozeb	4.2 + 120	7.2	4.2
Untreated	-	97.5	96.0

Curative activity is an important feature of the activity of myclobutanil on scab. Greenhouse and field experiments indicate activity of 96-120 h after infection at 12-15°C.

In addition to apple scab V.inaequalis, apple powdery mildew (Podosphaera leucotricha) is also a major disease of apples in Europe. Myclobutanil provided excellent control of primary and secondary infections of apple powdery mildew (P.leucotricha) on a 14 day spray schedule (Swait + Butt, 1985); a summary of the key results for myclobutanil in comparison with the standards is presented in Table 3.

TABLE 3

Control of primary and secondary mildew (P.leucotricha) on apples (cv Cox`s Orange Pippin) at Institute of Horticultural Research, East Malling, England in 1984 following a season-long programme of sprays at 14 day intervals.

Treatment	Dose (g a.i./100 l)	Primary mildew rating* 1984	Primary mildew (nos.spores /shoot ($x10^{-5}$)) 1984	Secondary mildew 13 Aug 1984	Extension shoot buds mildewed /tree 1985
Binapacryl	56	2.0	16	5.8	8.8
Triadimefon	2.5	1.0	24	1.1	2.7
Myclobutanil	6.0	0.0	4	0.3	2.3

*0 = 4 or more fully opened tip leaves healthy; 1 = 1-4 fully opened tip leaves healthy
2 = all tip leaves mildewed

Primary mildewed buds treated with myclobutanil produced new leaves free from mildew. The remaining mycelium was suppressed and the numbers of mildew spores produced from these shoots was significantly reduced. Hence early season use of myclobutanil reduces the source of inoculum for subsequent secondary infections.

Under high disease pressure on a trial site adjacent to an unsprayed orchard, myclobutanil controlled secondary mildew infections. The high level of control achieved with myclobutanil in 1984 was reflected in a low number of primary mildewed extension shoot buds in 1985. (Swait. person. comm.)

On less sensitive varieties and in lower disease pressure conditions, excellent control of powdery mildew (P.leucotricha) can be achieved with myclobutanil at 4.5 g a.i./hl, as demonstrated in trials in Germany, UK, Hungary, Poland, Rumania and Yugoslavia.

Myclobutanil has been tested on all the major European apple and pear varieties with no significant effects on fruit or tree growth. Fruit finish is particularly important for some pome fruits; Table 4 shows the results achieved on cv. Golden Delicious, a russet-sensitive variety.

TABLE 4

Influence of myclobutanil, as 40W and in mixtures with mancozeb and captan, on the russeting of apples (cv. Golden Delicious), Germany 1985 (Hoechst AG).

Treatment	Dose (g a.i./100 l)	Mean % fruits with russeting in 3 trials
Penconazole + captan	2.5 + 47.5	11
Myclobutanil + captan	4.5 + 50	11
Myclobutanil + mancozeb	4.5 + 80	10
Myclobutanil	4.5	13
Bitertanol	12.5	13
Untreated	-	17

Myclobutanil reduced russeting relative to the untreated and the performance was comparable to the standard bitertanol. Mixtures with mancozeb or captan tended to enhance fruit finish. Similar findings have been recorded in trials in the UK and Italy.

Laboratory tests at the Horticultural Centre, N Ireland demonstrated that myclobutanil had no effect on the germination of apple pollen (Watters. person. comm.).

Tests for taint of pome fruits were negative.

VINES

Trials throughout Europe have demonstrated that myclobutanil was very active against vine powdery mildew (Uncinula necator) and vine black rot (Guignarda bidwellii). Representative results are shown in Tables 5 and 6.

TABLE 5

Mean control of U.necator on leaves and grapes at 12 sites, Languedoc-Roussillon, France, 1985.

Treatment	Dose (g a.i./ha)	% infected Leaves	% infected Grapes
Myclobutanil	20	19.5	3.5
Myclobutanil	30	5.7	0.7
Fenarimol	18	19.1	5.9
Penconazole	25	12.3	0.1
Untreated		88.7 (74.5-100)	67.4 (29-93.3)

Under severe disease pressure conditions, myclobutanil controlled mildew on leaves and grapes when used on a 14 day preventative schedule. Applied after mildew infection, myclobutanil at 30 g a.i./ha also had a marked curative effect on vine powdery mildew.

On black rot (G.bidwellii) (Table 6) myclobutanil at 30 g a.i./ha was effective on bunches and grapes on a 14 day spray schedule.

TABLE 6

Mean control of G.bidwellii on bunches and grapes at 13 sites, France, 1983-84-85.

Treatment	Dose (g a.i./ha)	% infected Bunches	% infected Grapes
Myclobutanil	30	15.5	1.5
Mancozeb	1800	16.1	3.2
Triadimefon	75	19.2	4.0
Untreated		79.4 (61-95)	33.4 (19-82.6)

No phytotoxicity has been noted on any of the main European vine varieties, even at twice the recommended dose.

Myclobutanil has no influence on fermentation or wine quality.

CEREALS

Myclobutanil has shown promise as a seed treatment for the control of the major seed-borne pathogens (Table 7). In screening trials, control was achieved at the following application doses per 100 kg seed with good crop safety.

TABLE 7

Pathogen	Dose (g a.i./100 kg seed)
Ustilago nuda	10-15
Tilletia caries	10-15
Septoria nodorum	15-20
Fusarium spp.	15-20
Pyrenophora graminea	10-20

Control of foliar infections of Puccinia hordei have been outstanding at 10 g a.i./100 kg seed.

Development continues to define the effective dose for myclobutanil and the potential of mixtures to further broaden the disease spectrum.

OTHER CROPS

Myclobutanil has activity against the following diseases on other crops (Table 8).

TABLE 8

Crop	Pathogen	Dose (g a.i.)
Sugar Beet	Erysiphe betae Uromyces betae Ramularia betae	50-75/ha
Stone fruit	Sphaerotheca pannosa Tranzschelia pruni-spinosae Monilia laxa	5-7.5/hl
Cucurbits	Erysiphe cichoracearum Erysiphe polygoni	5-10/hl
Tomatoes/Peppers	Leveillula taurica	5-7.5/hl
Roses	Diplocarpon rosae Sphaerotheca pannosa Phragmidium spp.	5-10/hl

POST HARVEST DISEASES

Work in Italy (Gullino,Garibaldi. person. comm.) and Spain indicated that myclobutanil is promising at 0.1 g a.i./l as post-harvest dip treatments against Penicillium spp. of citrus.

CONCLUSIONS

Myclobutanil provided excellent control of a broad spectrum of diseases on crops throughout Europe. Control was achieved at low doses in a wide range of climatic conditions without any crop phytotoxicity.

On pome fruits, excellent control of foliar infections of apple powdery mildew (P.leucotricha) and scab (Venturia spp.) was obtained with myclobutanil at 4.5-6.0 g a.i./hl. The strong curative activity of myclobutanil was demonstrated by good suppression of primary mildew and a reduction in mildew inoculum. Against apple scab curative activity was achieved at 96-120 h post-infection at 12-15°C and should allow growers some flexibility in timing sprays. In high disease pressure conditions and with doses of 3.5-4.5 g myclobutanil/hl, the addition of a low dose of mancozeb or captan is considered necessary to control scab on the fruit.

Vine powdery mildew (U.necator) and black rot (G.bidwellii) were controlled on leaves and grapes with myclobutanil at 30 g a.i./ha at extended spray intervals even under severe disease pressure conditions.

Myclobutanil has shown considerable promise against a wide range of other diseases and work is underway to define timings and application doses.

ACKNOWLEDGEMENTS

We thank C Biroli, L Hede-Hauy, C Jousseame, A R Meakin, F Miserocchi, A Perrot and P R Sparrow, for their assistance in the preparation and review of this paper.

REFERENCES

Swait, A.A.J.; Butt, D.J. (1985). Fungicides to control apple powdery mildew; 1984 Trial A. Tests of Agrochemicals and Cultivars No.6 (Annals of Applied Biology 104, Supplement), pp. 36-37.

DF 125 - A NEW BROAD SPECTRUM FUNGICIDE

M. MASUI, N. YOSHIOKA

Dainippon Ink and Chemicals Inc., Agrochemical Department, Kamisumachi, Ibaraki, 314-02 Japan

R. I. HARRIS

Schering Agriculture, Stapleford, Nottingham, England

H. ROOS

Schering A.G. Pflanzenschutz, Dusseldorf, West Germany

A. CORNIER

Schering S. A., Division Agrochimie, Rungis, France

ABSTRACT

DF 125, the triacetate salt of 1,1'-iminodi (octamethylene) diguanidine, is a broad spectrum fungicide which controls a wide range of diseases in a number of economically important crops. It is a lipid biosynthesis inhibitor, and does not have systemic action. It has very good activity against benzimidazole resistant fungi.

Official field trials in Japan, which commenced in 1975, have demonstrated control of apple canker (Valsa ceratosperma), dormant stage blossom blight (Monilinia mali), cereal snow mould (Typhula ishikariensis), Fusarium snow blight (Fusarium nivale) and Sclerotinia snow blight (Sclerotinia borealis) of winter wheat. Citrus storage diseases, blue mould (Penicillium italicum), green mould (Penicillium digitatum) and black rot (Alternaria citri) have also been effectively controlled.

Extensive trials in West Europe with small grain cereals during the period 1984-86 have confirmed that DF 125, applied as a topical spray, is very effective against leaf spot and glume blotch (Septoria nodorum) and leaf spot (Septoria tritici) of winter wheat. Useful control has also been achieved of barley leaf blotch (Rhynchosporium secalis), net blotch (Pyrenophora teres), brown rust (Puccinia recondita), sooty moulds (Alternaria spp. and Cladosporium herbarum), ear blight (Fusarium spp.) and late powdery mildew (Erysiphe graminis) on ears.

INTRODUCTION

DF 125, the triacetate salt of 1,1'-iminodi (octamethylene) diguanidine, BEFRAN(R), is manufactured by Dainippon Imk and Chemicals Inc. using an industrial process previously considered unlikely to succeed (FAO 1978). It is a broad spectrum fungicide with considerable potential for controlling diseases in a wide range of agricultural and horticultural crops.

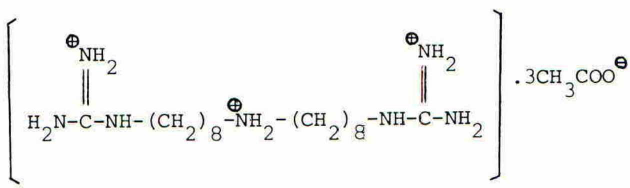
This paper describes the general properties of DF 125 and its field performance in extensive trials in Japan and Europe. Official trials in Japan since 1975 have been carried out on deciduous top fruit, citrus and wheat through the auspices of the Japan Plant Protection Association. In Europe, trials in small grain cereals during the period 1984-86 have been carried out by Schering AG.

TECHNICAL DATA

Chemical and Physical Properties

Chemical name: Triacetate salt of 1,1'-iminodi (octamethylene) diguanidine

Structural formula:



Molecular formula: $C_{24}H_{53}O_6N_7$
Molecular weight: 535.7
Melting point: 143.0-144.2°C
Solubility: Water 76.4g/100ml; methanol 77.7g/100ml; ethanol 11.7g/100ml
Formulation: 25% a.c. (250 g a.i./kg, 262 g a.i./l)

Mammalian Toxicity

Acute oral LD_{50} (a.i.): Rat (male) 326mg/kg, (female) 300mg/kg
Acute dermal LD_{50} (a.i.): Rat 1500mg/kg
Sensitization: Not a sensitizer
Irritation: Mild skin and eye irritant
Mutagenicity: Negative
Embryotoxicity: NOEL: 8 mg a.i.kg (gavage)

BIOLOGICAL ACTIVITY

In vitro agar impregnation tests have demonstrated DF 125 to have high growth inhibiting activity against many fungi of agricultural and horticultural importance (Table 1). Its mode of action is the inhibition of lipid biosynthesis.

(R) Registered Trade Mark of Dainippon Ink. and Chemicals Inc.

TABLE 1

<u>In vitro</u> fungicidal activity of DF 125

Pathogen	MIC (mg/l)
<u>Alternaria mali</u>	10
<u>Monilinia mali</u>	10
<u>Venturia inaequalis</u>	10
<u>Stereum purpureum</u>	0.62
<u>Valsa ceratosperma</u>	1.25
<u>Glomerella cingulata</u>	1.25
<u>Elsinoe ampelina</u>	10
<u>Endothia parasitica</u>	10
<u>Penicillium italicum</u>	1.25
<u>Fusarium nivale</u>	0.31

MATERIALS AND METHODS

Materials

A 25% a.c. (250 g a.i./kg, 262 g a.i./l) formulation of DF 125 was used in all trials. Comparisons were made with appropriate commercially available standard products used according to manufacturers' recommendations.

Methods

Trials were laid down as small plot replicated randomised block designs. Treatments were applied and assessments were made according to locally recognised practices and guidelines.

RESULTS

The results presented are a selection from the many trials undertaken and are representative of the performance of DF 125 under uniform and generally moderate to high disease pressure.

Deciduous top fruit

Trials in Japan against apple canker (<u>Valsa ceratosperma</u>), showed DF 125 to be marginally inferior to benomyl after the first season's treatment. However, the following year, its performance was much superior to the standard (Table 2). Control of dormant stage apple blossom blight (<u>Monilinia mali</u>) with DF 125 at 25 g a.i./hl was considerably better than the standard fluoroimide (Table 3).

TABLE 2

Control of apple canker (Valsa ceratosperma), Japan, 1978-80

Treatment	Dose (g a.i./hl)	% Control	
		1979	1980
DF 125	25	76	75
DF 125	50	80	92
Benomyl	25	88	48
Untreated (number of lesions/tree)		4.6	1.2
Application dates		21 November 1978 30 March 1979	24 October 1979 April 2nd 1980
Assessment dates		March-July 1979	April-July 1980

TABLE 3

Control of apple blossom blight (Monilinia mali), Japan, 1985

Treatment	Dose (g a.i./hl)	% Control
DF 125	25	100
Fluoroimide	75	37
Untreated (numbers of infected leaves/tree)		378.5

Citrus

DF 125 gave excellent control of Penicillium italicum when assessed 178 days after application. However, disease infections were very light (Table 4). Diaporthe citri and Alternaria citri were the major cause of losses and DF 125 gave good control, marginally superior to thiophanate-methyl. Against Penicillium digitatum DF 125 at 25 g a.i./hl gave good control but was inferior to the standard.

TABLE 4

Control of citrus storage diseases, Japan, 1981-82

Treatment	Rate (g a.i./hl)	% Control			
		P. italicum	P. digitatum	D. citri	A. citri
DF 125	12.5	100	33	60	55
DF 125	25.0	100	67	66	69
Thiophanate-methyl	47.0	100	100	56	52
Untreated (% decay of fruit)		0.8	2.4	34.7	53.8

Cereals

Trials programmes in Europe involved one or two applications according to disease pressure.

DF 125 is particularly active against Septoria spp. and has a flat dose response. At 262 g a.i./ha, the lowest dose tested, control of foliar symptoms was at least equivalent to that given by standards (Table 5). Evidence indicates that DF 125 is equally effective against S. nodorum and S. tritici. Development of brown rust (Puccinia recondita) was very well suppressed by DF 125 at 262 g a.i./ha in one of the 1986 United Kingdom winter wheat trials.

TABLE 5

Control of Septoria spp. on winter wheat foliage, Europe, 1984-86

Treatment	Dose (g a.i./ha)	Mean % Control					
		1984-85			1986		
DF 125	262	65		69	58	55	64
DF 125	393	66	62	77	60	71	66
DF 125	524	76	67		67		
DF 125	1048	83					
Prochloraz			43	74	37		
Triadimefon + captafol		66				73	73
Chlorothalonil		53			69	57	51
Chlorothalonil + carbendazim		60				61	56
Carbendazim + maneb				68			
Numbers of applications		1	1	2	2	1	2
Numbers of trials		7	4	7	1	4	2
Country		UK	D	F	F	UK	UK

D = West Germany, F = France, UK = United Kingdom

Good control of S. nodorum on the ears of winter wheat has been achieved (Table 6). Data from other wheat trials not reported here indicate that DF 125 is also active on sooty moulds (Alternaria spp. and Cladosporium herbarum), and ear blight (Fusarium spp.). Useful suppression of Erysiphe graminis on wheat ears has also been achieved but control of this disease on foliage is not satisfactory.

TABLE 6

Control of Septoria nodorum on winter wheat ears, Europe, 1985

Treatment	Dose (g a. i./ha)	Mean % Control		
DF 125	393	68	74	
DF 125	524	75	81	87
Prochloraz		57	43	65
Carbendazim + maneb				61
Captafol			79	
Prochloraz + captafol		77		
Numbers of applications		1	2	2
Numbers of trials		3	1	1
Country		D	D	F

Control of Septoria on foliage and ears has resulted in consistent and useful yield benefits ranging between 11-21%. Increases were at least comparable to those given by commercial standards (Table 7).

TABLE 7

Relative yields of winter wheat at sites where Septoria was the major disease, Europe, 1984-85

Treatment	Dose (g a.i./ha)	Mean % yield increase			
DF 125	262	6			10
DF 125	393	11	18	13	
DF 125	524	9	21	11	14
DF 125	1048	20			
Prochloraz			13	14	11
Triadimefon + captafol		13			
Chlorothalonil		11			
Chlorothalonil + carbendazim		12			
Carbendazim + maneb					11
Captafol				14	
Prochloraz + captafol			18		
Numbers of applications		1	1	2	2
Numbers of trials		3	2	3	7
Country		UK	D	D	F

Good activity against foliar diseases of barley has also been obtained, with control of R. secalis and P. teres equivalent to standard products in two years' trials in France (Table 8).

TABLE 8

Control of Rhynchosporium secalis and Pyrenophora teres on winter barley, Europe, 1985-86

Treatment	Dose (g a.i./ha)	Mean % Control			
		R. secalis		P. teres	
DF 125	262	65		50	
DF 125	393	74		59	
DF 125	524	83	52	65	56
DF 125	663	80		69	
Prochloraz		76	74	54	60
Propiconazole + mbc		84	76	45	47
Numbers of applications		2	2	2	2
Numbers of trials		5	2	3	1
Country		F	F	F	F

DF 125 applied just before snow cover gave very good control of all three snow moulds when assessed 174 days after treatment, superior to that given by mepronil + thiophanate-methyl (Table 9).

TABLE 9

Control of snow mould and snow blight on winter wheat, Japan, 1983-84

Treatment	Dose (g a.i./ha)	% control		
		Sclerotinia borealis	*Typhula ishikariensis*	*Fusarium nivale*
DF 125	250	91	72	86
Mepronil + thiophanate-methyl	750 + 350	76	52	0
Untreated (% infection)		10.0	5.0	60.0

In all trials undertaken in varying geographic locations and climatic conditions, DF 125 treatments did not cause any crop phytotoxicity.

DISCUSSION

DF 125 has given good control of a range of diseases affecting economically important agricultural and horticultural crops. Work in Japan has primarily shown DF 125 to have potential in deciduous top fruit and citrus, giving good disease control during the growing season, and also protection against some storage problems.

In Northern Europe, *Septoria spp*. are important pathogens of winter wheat and can limit production. Severe leaf infections can reduce yields by up to 25% and glume blotch by up to 50% (Gair *et al*. 1983). In addition, *S. tritici* is becoming increasingly resistant to the widely used MBC fungicides. The extensive trials carried out over the past three years have demonstrated the effectiveness of DF 125 against *S. tritici* and *S. nodorum*, and produced significant yield benefits. Useful control of other important cereal foliar and ear diseases has also been achieved. DF 125, with its novel mode of action, has very good potential for use either alone or in mixtures with other fungicides and development work is continuing in a number of countries.

REFERENCES

FAO; (1978) Evaluation of Some Pesticide Residues in Food, p.139

Gair, R.; Jenkins, J. E. E.; Lester, E. (1983) Cereal Pests and Diseases, 3rd Edition, Farming Press

BROAD SPECTRUM DISEASE CONTROL IN WINTER CEREALS WITH A COMBINED FORMULATION OF DPX H6573 PLUS CARBENDAZIM

J.R. AUSTIN

Du Pont (UK) Limited, Wedgwood Way, Stevenage, Herts. SG1 4QN

ABSTRACT

DPX H6573 plus carbendazim is a new preformulated fungicide for broad spectrum control of cereal diseases including *Pseudocercosporella herpotrichoides*, *Erysiphe graminis*, *Septoria* spp., *Puccinia* spp., *Rhynchosporium secalis* and *Pyrenophora teres*. Results from trials in winter cereals in the UK are presented for doses of 200 + 100 g a.i./ha and 160 + 80 g a.i./ha. Good levels of activity were shown against all diseases tested, this being reflected in yields equivalent or superior to current commercial treatments.

INTRODUCTION

DPX H6573 (bis(4-fluorophenyl)(methyl)(1*H*-1,2,4,triazol-1-ylmethyl)silane) is an ergosterol biosynthesis inhibiting fungicide first introduced by Du Pont in 1984 (Fort & Moberg 1984). The molecule has outstanding activity on a number of diseases in a range of economically important crops.

This paper reviews the fungicide's field performance as a foliar spray against diseases of winter cereals in the United Kingdom from 1984 to 1986 and demonstrates the improved spectrum and level of control that can be obtained with the addition of carbendazim as a preformulated mixture coded DPX N7872.

MATERIALS AND METHODS

All trials were sprayed using a modified hand-held Oxford Precision sprayer operating at 200 kPa. Treatments were applied in 200 l/ha water using Teejet 11002 fan-jet nozzles. Plots were generally 2 m x 12 m in size, replicated four times in randomised blocks, and were harvested with a mini-plot combine.

Trials in 1984 used a tank mixture containing a 2:1 ratio of DPX H6573 (40% EC) and carbendazim (75% WP) at the rates shown in table 1. In 1985 and 1986 this mixture was pre-formulated as a 37.5% EC, coded DPX N7872. Treatments used as standards for comparison were commercial formulations of prochloraz (40% EC; Sportak; FBC), prochloraz + carbendazim (55% EC; Sportak Alpha; FBC), propiconazole (25% EC; Radar; ICI), propiconazole + carbendazim (45% WP; Hispor; Ciba-Geigy), propiconazole + tridemorph (37.5% EC; Tilt Turbo; Ciba-Geigy), triadimefon + captafol (71.2% WP; Bayleton CF; Bayer)and flutriafol + captafol (42.2% EC; Impact Extra; ICI). Tridemorph (75% EC; Ringer; PBI) was also used in a tank mix with DPX H6573 + carbendazim for late season disease control in winter barley.

Control of Pseudocercosporella herpotrichoides was assessed by sampling 25 tillers per plot and scoring the extent of infection and penetration on a scale 0-3 (Scott 1971). Foliar diseases were evaluated using ADAS assessment keys, 2 to 6 weeks after application, taking 10 to 20 leaves per plot from either of the top 2 leaves. Results from several trials have been combined in many tables and mean results are presented. All crop stages were recorded using the Zadoks decimal growth stage key (Zadoks et al., 1974).

RESULTS AND DISCUSSION

Early Disease Control in Winter Cereals

With a trend towards early drilling of crops in recent years, the importance of good disease control with early fungicide applications is becoming more apparent. This is reflected in Table 1 where high levels of disease were recorded in trials 4 - 6 weeks after spraying.

Control of Pseudocercosporella herpotrichoides was lower than anticipated, possibly due to the severe disease pressure. Prochloraz at 400 g ai/ha showed best activity against P.herpotrichoides, but control with DPX H6573 + carbendazim 200 + 100 g a.i./ha gave a marked improvement over other treatments and some benefit over DPX H6573 200 g ai/ha applied alone. P.herpotrichoides resistance to carbendazim in the 1984 and 1985 seasons was recorded at 36% of the trials assessed. Similar control figures with both DPX H6573 + carbendazim doses in Table 1 is due to the higher disease pressure in 1985 when the 160 + 80 g a.i./ha dose was not used.

TABLE 1

Percentage Control of Stem and Foliar Diseases and Yield (as % of untreated plots) in Winter Cereals Following Application at Crop GS 31

Year:		1984-86	1984	1986	1984-86	1986	1986	1986	1984-86
Assessment:		P.herpotri-choides	E.graminis var.tritici	S.tritici	R.secalis	E.graminis var.hordei	P.teres	P.hordei	Yield
No. Trials:		53	2	1	7	3	2	1	41
% disease or yield (t/ha) of untreated plots:		69	12	16	28	13	11	0.3	7.4
Fungicide	Dose (g a.i./ha)								
DPX H6573	200	34	80	87	61	70	77	100	107.9
DPX H6573 + carbendazim	200+100	38	89	87	72	74	73	100	109.5
DPX H6573 + carbendazim*	160+80	38	83	87	65	66	77	100	106.9
Prochloraz	400	43	31	86	61	66	72	60	108.5
Propiconazole + carbendazim	125+100	27	84	83	61	73	64	60	106.1
Flutriafol + carbendazim**	118+188	20	-	89	40	44	77	100	105.4

* 1984 + 1986 results only

** 1986 results only

The addition of carbendazim to DPX H6573 also gave improved control of Erysiphe graminis and Rhynchosporium secalis compared to that given by DPX H6573 alone. Thus DPX H6573 + carbendazim at both doses demonstrated good activity on E.graminis, R.secalis, Septoria tritici, Pyrenophora teres and Puccinia hordei, superior to propiconazole + carbendazim (125 + 100 g a.i./ha) and prochloraz (400 g a.i./ha). This wider spectrum of activity was reflected in superior yields over three seasons' use.

Foliar Disease Control in Winter Wheat

The level of disease control at crop stages GS 39 and 59 highlighted the protectant and eradicant properties of DPX H6573 + carbendazim (Table 2 + 3). Applications at flag leaf emerged (GS 39) were made with only trace levels of disease present on leaves 1 and 2, whilst treatments applied at ear emerged (GS 59) coincided with higher levels of E.gramininis and Septoria species. Good disease control was obtained with DPX H6573 + carbendazim (160 + 80 g a.i./ha) at both timings and a significant improvement was noted over DPX H6573 (160 g a.i./ha) alone. Yield results with all treatments showed the benefit of an application at flag leaf emerged compared to the later timing.

A two spray programme was evaluated in 1985 and 1986 seasons with good levels of disease control in both cases (Table 4). DPX H6573 + carbendazim (160 + 80 g a.i./ha) as a double application or followed with a maneb + carbendazim (1600 + 250 g a.i./ha) spray showed disease control and yield responses equivalent to commercial applications.

Foliar Disease Control in Winter Barley

Applications of DPX H6573 + carbendazim (160 + 80 g a.i./ha) gave good control of E.graminis, R.secalis, P.teres and P.hordei 2 to 4 weeks after application (Table 5). The addition of tridemorph at 262 g a.i./ha to DPX H6573 + carbendazim (160 + 80 g a.i./ha) improved control of E. graminis in both years. Good activity was observed for DPX H6573 + carbendazim (160 + 80 g a.i./ha) 5 weeks after application, especially for control of R.secalis and P.hordei.

TABLE 2

Percentage Control of Foliar Diseases and Yield (as % yield of untreated plots) in Winter Wheat Following Application at Crop GS 39.

Year:		1984-85	1984-86	1985	1984-86
Assessment:		E.graminis	Septoria spp.	P.recondita	Yield
No. Trials:		12	15	1	20
% disease of untreated plots and yield (t/ha) of untreated plots:		16	22	20	8.2
% disease at application		1	3	0	
Fungicide	Dose (g a.i./ha)				
DPX H6573	160	51	57	79	109.8
DPX H6573 + carbendazim	160+80	71	76	91	111.9
Propiconazole	125	67	68	82	110.3
Triadimefon + captafol	125+1300	68	62	91	111.8

TABLE 3

Percentage Control of Foliar Diseases and Yield (as % of untreated plots) in Winter Wheat Following Application at Crop GS 59

Year:	1984-85	1984-86	1985	1984-86
Assessment:	E.graminis	Septoria spp.	P.recondita	Yield
No. Trials:	11	15	1	20
% disease of untreated plots and yield (t/ha) of untreated plots	14	23	30	8.2
% disease application	7	13	0	
DPX H6573	53	68	90	105.6
DPX H6573 + carbendazim	75	78	92	106.0
Propiconazole	68	74	88	106.1
Triadimefon + captafol	69	65	95	104.9

TABLE 4

Percentage Control of Foliar Diseases and Yield (as % of untreated plots) in Winter Wheat Following Two Applications at Crop GS 39 + 59

GS 39 Fungicide	GS 39 Dose (g a.i./ha)	GS 59 Fungicide	GS 59 Dose (g a.i./ha)	Year: 1985 Assessment: E.graminis No. Trials: 3 % disease or yield (t/ha) of untreated plots: 18	1985 S.tritici 4 28	1985 S.nodorum 1 9	1985 P.recondita 1 30	1985 Yield 6 7.40	1986 E.graminis 6 19	1986 S.tritici 5 24	1986 Yield 6 8.20
DPX H6573 + carbendazim	160+80	Maneb + carbendazim	1600+250	79	84	72	99	104.1	-	-	-
DPX H6573 + carbendazim	160+80	DPX H6573 + carbendazim	160+80	-	-	-	-	-	93	88	114.2
Propiconazole	125	Propiconazole	125	72	84	77	94	104.1	92	82	114.1

TABLE 5

Percentage Control of Foliar Diseases in Winter Barley Following Application at Crop GS 39

Year: Assessment:		1985 E.graminis	1985 R.secalis	1985 P.teres	1986 E.graminis	1986 R.secalis	1986 P.hordei
No. Trials:		1	3	1	1	2	1
% disease of untreated plots:		4	15	20	7	4	2
Fungicide	Dose (g a.i./ha)						
DPX H6573 + carbendazim	160+80	65	86	66	63	81	100
Prochloraz + carbendazim	400+150	52	74	67	–	–	–
Propiconazole	125	–	–	–	40	38	76
Propiconazole + tridemorph	125+250	–	–	–	59	43	70
DPX H6573 + tridemorph carbendazim	160+262+80	77	82	86	67	95	100

CONCLUSION

A mixed formulation of DPX H6573 + carbendazim offers excellent activity on all major foliar diseases of cereals with good control of carbendazim- resistant and sensitive strains of P.herpotrichoides. This outstanding broad spectrum activity is reflected in yields equivalent or superior to existing commercial treatments and thus offers the grower a useful advance in cereal disease control.

ACKNOWLEDGEMENTS

Thanks are due to the many farmers who have co-operated by providing trial sites and to colleagues at Du Pont who have assisted in this work.

REFERENCES

Fort, T.M.; Moberg, W.K. (1984) DPX H6573, a new broad-spectrum fungicide candidate. Proceedings 1984 British Crop Protection Conference - Pests and Diseases 2, 413-419

Scott, P.R. (1971) The effect of temperature on eyespot (Cercosporella herpotrichoides) in wheat seedlings. Annals of Applied Biology 68, 169-175

Zadocks, J.C.; Chang, T.T.; Konzak, C.F. (1974) A decimal code for the growth stages of cereals. Weed Research 14, 415-421

THE PERFORMANCE OF ANILAZINE IN MIXTURE WITH TRIAZOLE FUNGICIDES AGAINST LATE DISEASES OF WINTER WHEAT IN THE UNITED KINGDOM

A.J. MALCOM, D.J. BLUETT

Bayer UK Limited, Agrochem Division, Eastern Way, Bury St. Edmunds, Suffolk.

ABSTRACT

Anilazine is an S-triazine derivative fungicide which is active against a wide spectrum of diseases on a range of horticultural and agricultural crops, but is not currently recommended for use on cereals in the United Kingdom.

Trials were conducted over six years in the United Kingdom evaluating anilazine mixtures for late disease control in winter wheat. Two formulations of anilazine (trade mark 'Dyrene') were tested in two compound mixtures with triadimefon and triadimenol. The standard treatment in all trials was triadimefon + captafol (trade mark 'Bayleton CF').

Results indicated that anilazine was superior to captafol for control of *Septoria nodorum*. Overall in terms of *Septoria spp.* control, green leaf retention and yield the anilazine + triadimenol treatment proved to be more effective than the standard.

INTRODUCTION

Anilazine is the B.S.I. approved common name for an S-triazine derivative fungicide which was first reported to have fungicidal activity in 1955 (Wolf *et al.*, 1955). Full details of the molecular structure and toxicology have been published previously (Bayer A.G. 1983). Anilazine is a non systemic fungicide which is active against a range of leaf and fruit diseases on a wide range of agricultural and horticultural crops (Paulus *et al.*, 1970; Lacy, 1973; Comstock *et al.*, 1974; McCarter and Barksdale, 1977; Strider, 1978; Jordan *et al.*, 1983; Hims *et al.*, 1984).

Currently there are no recommendations for the use of anilazine in the U.K. but in view of the material's proven wide spectrum of fungicidal activity it was considered as a possible companion product for triadimefon or triadimenol as an alternative to the widely used mixture of triadimefon with captafol for late disease control in winter wheat.

MATERIALS AND METHODS

In the six harvest years 1980 to 1985 Bayer UK Ltd conducted 50 trials evaluating anilazine and captafol combinations with triazole fungicides for the control of late diseases in winter wheat. Sites were selected on the basis of potential disease risk, irrespective of treatments applied early in the season, and were normally on commercial crops.

Chemicals

In the early stages of this work, up to and including 1983 season, anilazine was available only as a 75% WP formulation (code number UK096a) but from 1983 onwards a suspension concentrate formulation (coded UK152) containing 480 g a.i./l was used. The following treatments were used in the trials:

1. Untreated check

2. 125g triadimefon/ha + 1300g captafol/ha.

   (Applied as 2 kg/ha of a WP formulation containing 6.25% triadimefon + 65% captafol)

3. 125g triadimefon/ha + 1875g anilazine/ha

   (Applied as a tank mix of 0.5 kg/ha triadimefon 25% WP + 2.5 kg/ha anilazine 75% WP)

4. 125g triadimenol/ha + 1920g anilazine/ha

   (Applied as a tank mix of 0.5 l/ha triadimenol 250 EC + 4 l/ha anilazine 480 SC)

5. 125g triadimenol/ha

   (Applied as 0.5 l/ha of triadimenol 250 EC)

Treatments were applied at a wide range of timings, the earliest being GS39 and the latest at GS69.

Trial Design

Most results reported here are from trials at 38 sites, consisting of 45 m^2 plots replicated four times in randomised block designs. Treatments were applied using carbon dioxide pressurised knapsack sprayers at application volumes in the range 222 -300 l/ha, achieved by spraying at 250 - 300 kPa through 80^{o} flat fan nozzles. Also included in the report are results from non-replicated grower trials at 12 sites, where treatments were applied through a range of commercial farm sprayers to plots between 1 ha and 2 ha in area. At 4 sites the treatments were applied twice, the first application at GS.39 and the second after GS.57.

Disease and Green Leaf Area (G.L.A.) assessments

These were normally made by sampling 10 tillers per plot, although 25 tillers per plot were sampled on grower trials, and scoring the top 3 leaves of each on a 0-9 logarithmic scale of percentage cover.

Yields

Yields were determined using a combine harvester modified for small plot work except in the case of the grower trials where a known area of crop was harvested with the grower's machine. All yields are quoted at a standard 86% dry matter.

RESULTS AND DISCUSSION

The change from using triadimefon + anilazine WP to triadimenol + anilazine SC was effected after 1983 when there were seven trials laid down enabling both mixtures to be compared directly. It is clear from the disease data obtained from the three sites where significant levels of Septoria were observed (Table 1) that triadimenol + anilazine SC gave better control of leaf septoria.

TABLE 1

Mean % control of Septoria spp. on the top two leaves from trials including both anilazine formulations.

Treatments	TRIALS ER/20/83 (Cambs)	 SR/27/83 (Kent)	 WR/24/83 (Hereford)	Mean
Untreated (% cover)	(10)	(15)	(32)	(19)
125g triadimefon + 1300g captafol	38	53	64	52
125g triadimefon + 1875g anilazine WP	36	73	93	67
125g triadimenol + 1920g anilazine SC	51	85	95	77

In Tables 2 to 7 it is not realistic to compare the two anilazine mixtures directly because data for the two combinations was obtained from different sites in different seasons. All the discussion therefore relates to comparison with data for untreated check plots and the triadimefon + captafol which was included in all trials as a standard enabling it to be compared directly with either anilazine mixture.

Control of Septoria spp.

At most sites mixed infection of S.nodorum and S.tritici occurred and therefore all the results have been combined. Both anilazine mixtures gave better reduction of disease than triadimefon + captafol (Table 2).

TABLE 2

Mean % reduction in cover of Septoria spp. assessed 17 - 50 DAT (Mean = 32 DAT)

Treatments	Number of sites 15	21
125g triadimefon + 1300g captafol	42	44
125g triadimefon + 1875g anilazine WP	53	-
125g triadimenol + 1920g anilazine SC	-	55

At sites where only one species of Septoria was found, indications of treatment efficacy against the specific pathogens were obtained. S.nodorum alone was found at 3 sites (Table 3) and triadimenol + anilazine SC was superior to the triadimefon + captafol.

TABLE 3

Mean % reduction in cover of Septoria nodorum on leaf 2

Treatments	TRIALS SR/27/83 (Kent)	WR/54/85 (Wilts)	SC/22/85 (Perths)
Untreated (% cover)	(29)	(74)	(43)
125g triadimefon + 1300g captafol	51	72	42
125g triadimefon + 1875 anilazine WP	72	-	-
125g triadimenol + 1920g anilazine SC	85	76	54
125g triadimenol	61	-	-

It is not certain whether the triadimenol or anilazine was responsible for the additional level of control, but it is likely that some increase came from both. At site SR/27/83 triadimefon + anilazine WP gave better control (72%) than triadimefon + captafol (51%). Since both treatments included the same rates of triadimefon it is reasonable to assume that anilazine was more effective than captafol in controlling S.nodorum.

Triadimenol alone was also included at site SR/27/83 and gave 61% control. Triadimenol has been found by other workers (Best & Jordan 1985) to reduce S.nodorum.

S.tritici alone occurred at one site and triadimenol + anilazine was once again superior to triadimefon + captafol (Table 4).

TABLE 4

Mean % reduction in cover of Septoria tritici on leaf 2 in a Lincolnshire trial MR/23/85

Treatments	% Reduction
Untreated (% cover)	(36)
125g triadimefon + 1300g captafol	48
125g triadimenol + 1920g anilazine SC	60

Green Leaf Area (G.L.A.) Retention

In late spray trials on cereals, green leaf area is a useful measure of the overall effect of disease complexes on the plant and it can give indications of the benefits from treatment. In the trials reported here triadimefon + captafol and the two anilazine mixtures enhanced G.L.A. retention by similar amounts (Table 5). Septoria spp. were the major factor other than natural senescence reducing green leaf area, although other diseases, notably mildew (Erysiphe graminis), brown rust (Puccinia recondita) and Alternaria sp. were responsible for damage in some trials.

TABLE 5

Mean green leaf area retention on top 3 leaves assessed 21 - 42 DAT (Mean = 33 DAT)

Treatments	Mean % Green Tissue at 11 sites	Mean % Green Tissue at 12 sites
Untreated	58	67
125g triadimefon + 1300g captafol	68	72
125g triadimefon + 1875g anilazine WP	71	-
125g triadimenol + 1920g anilazine SC	-	74

Yields

Grain yield was measured on a total of 36 sites and the mean yield increase over untreated from triadimefon + captafol was 6% (actually 498 kg/ha) (Table 6).

TABLE 6

Mean grain yield relative to untreated

Treatments	Numbers of sites		
	36	17	21
Untreated (kg/ha)	100 (7853)	100 (7525)	100 (7997)
125g triadimefon + 1300g captafol	106	105	107
125g triadimefon + 1875g anilazine WP	-	105	-
125g triadimenol + 1920g anilazine SC	-	-	109

The overall conclusion from yield data is that both anilazine mixtures gave comparable yields to triadimefon + captafol with an indication that triadimenol + anilazine SC may have been slightly better. This is further substantiated by the results of ADAS trials in 1984 (M.A.F.F. 1984) where triadimenol + anilazine SC was compared to triadimefon + captafol following a common treatment at GS.31. In the 36 experiments triadimenol + anilazine yielded 10.83 tonnes/ha and triadimefon + captafol 10.77 tonnes/ha. In 1985 a similar series of 36 trials was conducted (M.A.F.F. 1986) giving a very similar result, with triadimenol + anilazine and triadimefon + captafol yielding 8.04 and 7.98 tonnes/ha respectively.

TABLE 7

The effect of spray timing on mean grain yield relative to untreated

Treatments	Treatments applied at or before GS 51 at 10 sites	Treatments applied after GS 51 at 7 sites
Untreated (kg/ha)	100 (7229)	100 (8662)
125g triadimefon + 1300g captafol	108	104
125g triadimenol + 1920g anilazine SC	110	106

The effect of spray timing on yield is considered in Table 7. The results indicate that triadimenol + anilazine was slightly better than triadimefon + captafol at both application timings.

CONCLUSION

The trials reported here and those conducted by independent bodies indicate that triadimenol + anilazine was more effective than the triadimefon + captafol standard and could therefore be a satisfactory alternative for the control of late diseases in wheat.

ACKNOWLEDGEMENT

The authors would like to thank all the farmers who co-operated by providing sites for the trials and colleagues within Bayer UK Limited who conducted the trials and assisted in the preparation of this paper.

REFERENCES

Bayer A.G. (1983) Dyrene® Technical Information Bulletin, Bayer Pflanzenschutz Leverkusen.

Best, G.R.; Jordan V.W.L. (1985) Evaluation of fungicides for control of Septoria nodorum in Winter Wheat. Tests of Agrochemicals and Cultivars 6 (Annals of Applied Biology 106, Supplement), pp. 74-75.

Comstock, V.C.; Martinson, C.A.; Epstein, A.H. (1974) Fungicidal Control of Southern Corn leaf blight on Texas male-sterile corn. Plant Disease Reporter 58, 104-107.

Hims, M.V.; Dickinson, C.H.; Fletcher, J.T. (1984) Control of Red thread, a disease of grasses caused by Laetisaria fuciformis. Plant Pathology 33, 513-516.

Jordan V.W.L.; Best, G.R.; Allen, E.C. (1983) Glasshouse evaluation of fungicide treatments for control of barley net blotch. Tests of Agrochemicals and Cultivars 4 (Annals of Applied Biology 102, Supplement), pp. 56-57.

Lacy, M.L. (1973) Control of Septoria leafspot of celery with systemic and non systemic fungicides. Plant Disease Reporter 57, 425-428

M.A.F.F. (1984) Jenkins, J.E.E. Personal Communication.

M.A.F.F. (1986) Cereal Diseases 1985; ADAS Northern Region technical news: Plant Pathology.

McCarter, S.M.; Barksdale, T.H. (1977) Effectiveness of selected chemicals in controlling Rhizoctonia fruit rot of tomato in greenhouse and field tests. Plant Disease Reporter 61, 811-815.

Paulus, A.O.; Shibuya, F; Holland, A.H.; Nelson, J. (1970) Timing interval for control of Septoria leaf spot of celery. Plant Disease Reporter 54, 531-535.

Strider, D.L.; (1978) Alternaria blight of Carnation in the greenhouse and its control. Plant Disease Reporter 62, 24-28.

Wolf, C.N.; Shuldt, P.H.; Baldwin, M.M. (1955) S-triazine derivatives - A new class of fungicides. Science 121, 61-62.