EVENING DISCUSSION

CROP PROTECTION RESEARCH. WHO DECIDES? WHO BENEFITS?

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Crop protection research. Who decides? Who benefits?

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ABSTRACT

This paper discusses the issues surrounding some of the forces that have shaped the direction of agricultural R&D. More specifically, it attempts to briefly explore who actually carries out the research and who benefits from it? The view taken is that there are so many pressures on research and researchers that the supposed intended beneficiaries are often left out of the equation when research agendas are set. Thus mistrust, misunderstandings and low adoption of new technologies is almost inevitable. Although a relatively new phenomenon in the UK, this lack of adoption has a long history in developing countries agricultural R&D. An historical analysis of participatory methods in developing countries agriculture R&D illustrates that these systems evolved partially as a response to these failures and also because they address vital and until recently unrecognised aspects of agricultural research that are of paramount importance if successful adoption of new technologies is to be achieved. This paper proposes that we, in the UK, have plenty to learn from these approaches. Furthermore, that now might prove to be an ideal time to re-import participatory methods to the UK.

INTRODUCTION

A question:

Do we as crop protection researchers take on board the needs of those meant to benefit from our work and use this information to direct our activities?

Most, if not all, of us would probably answer an emphatic 'yes' in the sense that crop protection is important to all those who grow crops! The ultimate aim is to help producers even if research varies in terms of immediate impact. In other words we are engaged in applied research, and there is nothing that says that applied science cannot also be good science.

Yet perhaps we would also recognize the complications in the previous paragraph. Exactly who are these producers that are the meant to ultimately benefit from the applied research? Producers are a highly diverse group and is it realistic to assume that all of their needs are the same? Is it also realistic to assume that the producers are the only intended beneficiaries of the research? If the research is being funded by a commercial agency then surely the company will also want to benefit. If the work is public-funded or paid for by a charitable foundation then will not the funder want to ensure that the work at least matches there own agenda? Even these 'public-good' bodies can be minefields of conflicting and evolving agendas.

Also, what about the researchers themselves? Most of us are paid a salary, albeit with great diversity in remuneration and conditions, and most of us have to compete with other researchers for funds, prestige, promotion, and, unfortunately, increasingly for survival. Naturally we all want results that are exciting, publishable and which lead to further research rather than being an 'end'. Are all of these desires compatible? Finally what about the retail chain and the consumer? Retailers may welcome anything that helps reduce costs to farmers if it means that they can buy cheaper. Consumers usually want good quality and cheap produce that is as conveniently available as possible.

Given this complexity it is not surprising that the issue of matching research effort to impact on the lives of those intended to benefit has long been analysed. Generally the conclusion reached is that the chance of a dysfunction is highest when those setting the research agenda don't interact with those meant to benefit i.e. when we have poor, if any, stakeholder participation. In the developed world, agriculture has increasingly moved away from this towards being a business and participation is driven by concerns of demand and supply. Meaningful dialogue in this context may be limited to a particular type of market research. Even the public funding agencies such as BBSRC and DEFRA have increasingly stressed research that may found the basis for future saleable technologies (e.g. the Foresight Programme), while at the same time placing the emphasis on the support of 'excellent science'.

Yet something appears to be wrong.

At least one group of stakeholders, the consumers, appear to be highly suspicious and wary of farmers and farming, and this nervousness is impacting on our politicians. Consumers don't appear to like what they hear, helped by evocative headlines such as 'Frankenstein Food'. The status of farming is at an all time low.

We will attempt to argue in this paper that developed countries have much to learn from the very practices which agencies such as the UK government's Department for International Development (DFID) have been promoting in the South; participation that is based on genuine dialogue with stakeholders rather than just the market.

Let it first be said that an essay of this length cannot possibly hope to capture the wealth of the 'participatory' literature that has emerged over the past 30 years. Neither are we able to do full justice to the extensive debates and literature surrounding the changes in the way agricultural research has been funded in the UK. What we will attempt to do is provide a few points for discussion and maybe provide some (non-GM) food for thought! A more in-depth discussion of some of the points we raise can be found in Buhler *et al.* (2002).

PARTICIPATION IN AGRICULTURAL DEVELOPMENT

Much of the developing world, the south, has emerged out of a colonial past where the formal agricultural research agenda were set by an external power for the benefit of that power. Research emphases tended to be on production (extent and yield) and quality (for export). Normative science and formal, reductionist research methods were adopted to verify the superiority of modern (i.e. 'northern'), often exotic, materials and technologies over indigenous ones. However, this approach has been shown to have had only partial success (Chambers, 1983, 1997) due, in part, to the:

1. lack of the human dimension in the research process
2. obsession with yield maximisation at almost any cost
3. dominance of disciplinary and reductionist science and its consequences
4. weakening of linkages between research, education, extension and practice.

Lessons were learnt and the 1970s saw a watershed in the relationship between researcher and those meant to benefit. New approaches were developed to help overcome the barriers including Rapid Rural Appraisal (RRA) and Farming Systems Research (FSR). They assume that in order to know how best to intervene one needs to understand something of the richness and connectedness of how people live.

Initially these approaches were extractive and the intention was for those implementing them to learn from those to which the techniques were being applied. However, RRA was superseded by Participatory Rural Appraisal (PRA) in the early 1980s and Participatory Learning and Action (PLA) in the 1990s. PRA and PLA are more about using the visual tools and techniques to go beyond an extractive process and to help people understand their condition and maybe see ways of using their own power and abilities to overcome the difficulties they may face (Chambers 1993, 1997). Hence they are all about words such as 'facilitation' of change (Sellamna, 1999). Stakeholder participation has also become a matter of human dignity and rights, and hence is non-negotiable (Pretty, 1998).

Participatory techniques, and indeed the very ethos of stakeholder participation, have become very popular amongst development agencies, including those engaged in agricultural development and research and those working within a livelihood context. Yet for all this appeal all is not rosy in the participatory garden. Practical attainment can be difficult as the approaches can be time-consuming, require a team approach with a variety of skills and by their very context-specific nature can resist generalization. These points are especially relevant given the funding insecurity and instability in the agricultural research sector of many developing countries (Pardey *et al.*, 1995; Maredia *et al.*, 1997; Monyo, 1997; Idachaba, 1998; World Bank, 2000a and 2000b). Also, it has to be said that they are hardly an appealing set of characteristics for those of us whose very worth is measured by our bosses strictly in terms of measurable outputs (quantity of 'blue chip' grant income, number of refereed journal papers etc.).

There are also suspicions that funders may see such participation as an easy (and cheap) way of helping to 'do' development, and may even serve to discretely shift the responsibility for being poor to the poor themselves! At a basic level doing PLA is no guarantee that people's lives will improve or even that they will be empowered (Bevan, 2000). It can quite literally be participation for participation sake (Sellamna, 1999). The appealing rhetoric has also meant that the term 'participation' has been hijacked by everyone who finds it convenient to do so and its meaning can vary from contracted forms of interaction to a truly co-learning mode of operation (Sellamna, 1999). However, while such critiques of the 'participatory' family has grown in recent years care has to be taken not to throw the baby out with the bathwater.

How does all this relate to crop protection? It is perhaps of no surprise that participatory techniques have also become central to many crop protection initiatives in the developing world. They are usually equated with:

- using participatory techniques to help guide the crop protection research agenda (i.e. in a needs assessment context)
- farmer field schools which attempt to introduce Integrated Pest Management (IPM)

However, it can be argued that neither of these is truly at the PRA/PLA end of the participation spectrum. The first is usually an extractive process, while the second can be one-way ('top down') learning (researchers 'teach' Southern farmers the wisdom of the North) rather than being truly participatory (Morse and Buhler, 1997).

AGRICULTURAL RESEARCH AND PARTICIPATION IN THE UK

So what does the above tell us about participation in agricultural research in the UK? An historical analysis might well indicate that, in the UK, we did have what could have called a participatory research system. Farmers have been heavily involved in research and setting the research agenda - right through from Turnip Townshend up until arguably the 1970's. Since then Agricultural R&D has undergone an increased transition from field level biology to molecular biology. Agriculture also had the support of consumers and politicians alike. You could even argue, that as an industry it even had its own Ministry - MAFF, which provided a direct line of communication from farming to policy making. This enabled research to be directed to the needs of the farmers more directly than is the case today. Since then there has been a well documented acceleration of the amount of science involved in agriculture - the so called "industrialisation of agriculture". From the 1980's onwards this process of vertical integration has increased. Farming is now a part of agribusiness and undoubtedly that has brought many benefits to society - not least cheap and plentiful food. So what is the problem? Why is there now mistrust of the science and scientists, farmers, politicians and the companies involved in agricultural science? In answering this, it is perhaps better to ask the question; "What has this process resulted in for the multiple stakeholders in agriculture and agricultural research?" Few could argue that farmers have lost a lot of autonomy over agronomic decision-making and the general running of their farms. Similarly, it is possible to say that with the growth of supermarkets, the consumer now feels more distanced from the process. Given then, that there has undoubtedly been a shift in the relationships between producer, consumer and policy maker, where has this left agricultural R&D? As early as 1971 Lord Rothschild tried addressing this question in his report, "The organisation and management of Government R&D" (Rothschild, 71). This report did highlight that there was, even then, a dilemma over the allocation of resources for applied and pure research. This implies that control is exerted over the allocation of resources and the direction and management of R&D. Furthermore, it points out that there has to be flexibility and room to respond to shifting needs and responsibilities. Therefore, given that since then, there has been an increase in the amount of commercial private sector R&D, it follows that there may be a danger of R&D being led away from the needs of society more towards those of commercial interests. This perception might go some way to explaining why it is that the public has lost some faith in science. Add this to the BSE and Foot and Mouth disasters and it is easier to understand this view of science. As for government involvement it is no longer clear what DEFRA stands for. Are they acting as a proxy contractor for the farmer, consumer, industry, wildlife - everyone, who? No wonder there is confusion.

Certainly, according to the media, this is the populist view - farmers are damaging the environment and politicians, scientists and multilateral companies cannot be trusted and are all serving their own interests at the expense of society. The poor old consumer is being held to ransom. What consumers do not perhaps realise, or choose to ignore, is that they cannot have it both ways. On the one hand they openly berate the system, whilst on the other, support it by shopping at supermarkets. If, as it would appear, the dichotomy of public R&D versus private R&D is becoming less and the two are now closer with government encouraging these links, then

possibly the issue becomes one of accountability and power. Large private corporations are perceived to be less accountable than elected governments and thus more powerful in setting research agendas. If government is becoming less willing or able to dictate terms for agricultural R&D and the private sector is appearing to be unwilling to listen to concerns, then it is no wonder that a growing proportion of consumers are going to feel disempowered.

It is here perhaps that the adoption of a more participatory approach could be seen to be beneficial. There are now increasing numbers of valuable experiences from the industrialised countries (e.g. Cerf *et al.*, 2000; Hamilton, 1995; Roling & Wagemakers, 1998) which will help to inform us of the value of farmer-partnerships and integrated systemic learning and researching towards most sustainable agriculture.

GLOBALISATION AND SUSTAINABILITY

We are always being told that we live in an increasingly globalized world. But globalization is not just about money, it is also all about a sharing of culture and ideas and this also applies in science (Bonte-Friedheim, 1997). All too often we think of globalization in terms of the reach of multinational corporations marketing pesticides and germplasm; the globalization of crop protection components. This is distinct from the globalization of an ideology, such as IPM, that is perhaps less immediately apparent. Nevertheless we should remind ourselves that IPM emerged out of a reaction to the environmental problems resulting from indiscriminate use of persistent, non-selective and toxic pesticides in the developed world. Yet IPM is now promoted by scientists based in the north to farmers who perhaps have never used a pesticide or indeed couldn't afford it even if available (Morse & Buhler, 1997). The same may also be true with that other exported ideology from the north inexorably linked with crop protection – agricultural sustainability. Farmers all over the world have long been interested in 'sustainability' but what it means to them will vary enormously (Roling & Wagermakers, 1998).

Ironically, if they are asked, farmers in the south may often request for specific technologies such as pesticides or resistant varieties to help them with crop protection rather than an ideology such as IPM or something even vaguer such as sustainability. Understandably, farmers wish to maintain control over what they do as well as how and when they do it, and concerns over crop protection are balanced within an over-arching strategy for livelihood enhancement or perhaps just survival. Sustainability is seen in terms that may not match the vision of an external 'northern' based scientist. Yet participation presents problems both in the north and south. For example, while the use of pesticides and indeed pest-resistant GM varieties may fit into the farmer's agenda they may not match those of other stakeholders such as the consumers. But this is not to say that we couldn't talk to all these groups and at least arrive at an understanding of the points of convergence and divergence.

The question we need to ask is whether the north could benefit from a re-exporting of participation from the south? Unlike IPM and sustainability which are applauded as much in the north as the south, even if application has been a moot point, stakeholder participation has largely been a one-way export. While there is no doubt that the participatory family has been a powerful force in the development of ideologies and techniques for the outh their application in the north has been limited to areas such as soft system methods (for institutional learning) and in contexts such as 'deliberative institutions' within urban development and Local Agenda 21 (Bell and Morse, 1999). A great deal of experience exists as to how best to bring stakeholders

together and encourage them to express and share ideas even if this experience is perhaps more extensive and richer in Southern contexts.

When we have posed this question before it is interesting to note that the answers we receive often revolve around the public-private axis. To summarise, given that participation is often confused with 'democracy', and that the public are the ones who ultimately provided the funds in the first place, stakeholder participation is seen as acceptable and perhaps desirable in the publicly funded research sector. Participation is listening to the customer, and hence typically crystallized as market research with no desire to take it further. In the publicly funded research sector the power and structures still favour a research system that promotes accountability measured in very specific ways (especially with outputs such as publications). Some argue that these very structures and systems will not facilitate a more participatory style as they are somehow incompatible (Edwards-Jones, 2001). One cannot help but have some sympathy with the following view:

"*Even if the aim of the participatory research were to achieve social benefits it could prove difficult to persuade panels of research grant referees, who would probably be traditional scientists, that involving farmers in problem identification was a justifiable activity.*"

It's not just a simple matter of saying that participation will not work under the sort of input-intensive cropping systems in the UK - it works on similar systems elsewhere (Witcombe, 1999). It is far more about the way in which we like to do things, our research culture, which in turn has been driven by the society in which we live.

In the private sector such a narrow perspective on market research could potentially over-emphasise the immediate customer, typically the producers, and ignore other stakeholders whose views may ultimately be decisive. Indeed can we say that there is such a divide between the public and private sectors? At least when it comes to DEFRA and BBSRC funding in the UK there is much emphasis on partnership between the two. If the private sector receives public funds then shouldn't the principle of stakeholder participation apply? DFID, at least in terms of rhetoric, is very positive about the role that private enterprise can play in development. Yet are there differences between the rhetoric and reality? For example, while personnel of the the DFID funded Crop Protection Programme (CPP) are positive about the role that private enterprise can play in helping to achieve its mandate the evidence suggests that the vast bulk of its funded projects are implemented by the public sector. For example, of the projects listed in the 2001 publication 'Perspectives on Pests', covering the period 1996 to 2000, 46% of the 'implantation' was by the higher education sector (mostly just one - the Natural Resources Institute, Chatham) and 48% by public research institutes. The remaining 6% includes government departments and non-government organizations as well as the private sector. One can't help but wonder whether a greater opportunity is being missed.

CONCLUSIONS

So where does this leave us with regard to our initial questions: who benefits and who pays? Clearly we have been dealing with a complex topic. What we think are easy and clear answers upon further reflection become intricate and interwoven with a multitude of concerns and interests. We in the north have been all to ready to proclaim that the south should follow our example and adopt our technologies. The participatory movement was also a product of the

north as indeed was IPM and the modern notion of agricultural sustainability. Yet all of these were reactions to our failures, but only two of them (IPM and sustainability) have been seen as necessary for the north as well.

We have sufficient evidence from many research systems, both from the north and the south, that stakeholder participation can be complementary to existing research approaches and, most importantly, they can liberate and empower farmers as well as consumers and even retailers. Some would say that we already do this but do we do it early enough and are we sincere? In our view the crop protection industry needs an entirely new perspective in the way in which it operates. Given that there has undoubtedly been a sea change in the relationships between all of the stakeholders involved, is it not logical that we need a fusion of participatory mindsets based on the market and dialogue. The problem is how to instil such a mindset and, perhaps ironically, we believe that key to promote such a change does not rest solely in the public-funded institutions, including the universities, with their straight-jacketed obsessions with accountability measured in very narrow terms, but the private sector. We suggest that these participatory techniques can be thought of as another way of doing market research and hence helping to avoid expensive investment delivering something that at best no one may want and at worse serve as a *cause celebré* for groups looking for examples of the failures of the global market. A revolution in market learning that takes on board multiple stakeholder perspectives in a participatory mode, as for example currently being tested in the CACTUS project (Bamforth and Brookes, 2002) in consumer-idealized design (CID; Pourdehnad and Robinson, 2001) or even within the broad field of market learning (Adams *et al*, 1998), may be the spur to help liberate the public sector from its imposed prison of introspection. Such participatory market learning (PML) may provide a spur for the strengthening of the private-public partnership in the UK .

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SESSION 5A

NEW COMPOUNDS, FORMULATIONS AND USES FOR DISEASE MANAGEMENT

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Papers: 5A-1 to 5A-5

HEC5725: A novel leaf-systemic strobilurin fungicide

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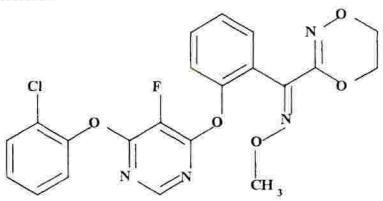
ABSTRACT

HEC5725 is a leaf-systemic broad-spectrum fungicide from the chemical class of dihydro-dioxazines currently being developed for use mainly in cereal crops. The compound provides both a rapid initial effect and prolonged activity due to its protective and leaf systemic properties. Applied as a foliar spray in cereals, HEC5725 provides excellent control of Septoria leaf spot (*Septoria tritici*), Septoria leaf and glume blotch (*Leptosphaeria nodorum*), rust (*Puccinia recondita, P. striiformis, P. hordei*), Helminthosporium diseases in wheat and barley (*Pyrenophora tritici-repentis, Pyrenophora teres*) as well as scald (*Rhynchosporium secalis*) and powdery mildew (*Blumeria graminis* spp.). Furthermore, seed and soil-borne diseases like snow mould (*Monographella nivalis*) and common bunt (*Tilletia caries*) are also efficiently controlled, when HEC5725 is used as a seed treatment. Mixtures of HEC5725 with selected fungicides often result in an increased biological activity against these diseases. HEC5725 has a favourable regulatory profile.

INTRODUCTION

HEC5725, from the chemical class of dihydro-dioxazines, was discovered in 1994 and patented by Bayer AG. It has been developed as a foliar fungicide and for seed treatment, mainly for cereal crops. Commercial introduction into the main European markets is scheduled for 2004. This paper describes its chemical properties, toxicological profile, environmental behaviour, systemicity, fungicidal spectrum of activity as well as its performance in the field.

CHEMICAL AND PHYSICAL PROPERTIES

Common name:	Fluoxastrobin (ISO-accepted)
Chemical class:	Dihydro-dioxazines
Code number:	HEC5725
Appearance:	white, crystalline solid, with slight characteristic odour
Structural formula:	
Molecular formula:	$C_{21}H_{16}ClFN_4O_5$

Chemical name (IUPAC):	{2-[6-(2-chlorophenoxy)-5-fluoropyrimidin-4-yloxy]phenyl}(5,6-dihydro-1,4,2-dioxazin-3-yl) methanone O-methyloxime
Vapour pressure:	6×10^{-10} Pa (at 20°C extrapolated)
Solubility (water):	2.29 g/L (at 20°C at pH 7)
Partition coefficient:	Log Pow = 2.86 (at 20°C)

TOXICOLOGY, ECOBIOLOGY AND BEHAVIOUR IN THE ENVIRONMENT

Acute oral rat (LD_{50}):	> 2500 mg a.i./kg b.w.
Acute dermal rat (LD_{50}):	> 2000 mg a.i./kg b.w.
Eye irritation:	irritating to eye of rabbits
Skin irritation:	not irritating to skin of rabbits
Sensitisation:	no skin sensitisation observed in guinea pigs
Mutagenicity:	no genotoxic effects observed
Subchronic, chronic:	no evidence of primary embryotoxic, reproductive or teratogenic potential either in rats or in rabbits. no carcinogenic and neurotoxic potential.
Acute oral quail (LD_{50}):	> 2000 mg a.i./kg b.w.
Earthworms (LC_{50}):	> 1000 mg a.i./kg d.wt.s.
Rainbow trout, acute 96 h (LC_{50}):	> 0.44 mg a.i./litre
Honey bees (LD_{50}):	oral: > 843 µg/bee, contact: > 200 µg/bee
Water fleas, acute 48 h (EC_{50}):	0.48 mg a.i./litre
Stability in soil (DT_{50}):	16-119 days

MODE OF ACTION AND SYSTEMICITY

HEC5725 was designed in a synthesis programme for new broad spectrum methoxyacrylates, but with the additional aim of combining good protective and long lasting efficacy, which is typical for products from this chemical class, with distinct leaf systemic properties. It is chemically a strobilurin analogue and like azoxystrobin or other methoxyacrylates it inhibits electron transport between cytochrome b and c_1 within the respiratory chain (Godwin *et al.*, 1992). HEC5725 affects both the early phases of the fungal infection process, like spore germination, germ tube growth and penetration into the leaf, and also mycelial growth, providing very good protective and curative properties. The excellent leaf systemicity shown by HEC5725 is the basis for its rapid uptake and an even, acropetal distribution of the active substance in the leaf. Due to very good plant compatibility, its penetration through the cuticle into the leaf can be further optimised by using corresponding formulation types.

In contrast to its very high leaf systemicity, uptake via seed and roots is visibly lower as demonstrated by tests with radio-labelled compound. A seed treatment with HEC5725 provides both very good broad-spectrum disinfestation and a long-lasting protection of the young seedling from seed and soil-borne pathogens. However, wind-borne diseases like powdery mildew or net blotch of barley are not controlled if HEC5725 is applied to the seed.

SPECTRUM OF ACTIVITY AND PERFORMANCE IN FIELD TESTS

HEC5725 exhibits a broad spectrum of activity against fungi from the Ascomycetes, Basidiomycetes, Deuteromycetes and Oomycetes in cereals, potatoes, vegetables and coffee as main target crops (Table 1).

Table 1. Spectrum of activity of HEC5725

Crop	Rate (g a.i./ha)	Excellent activity	Good activity	Side effects
Cereals	200	Septoria leaf spot Septoria glume blotch Brown rust Stripe rust Tan spot *Fusarium nivale* Scald Net blotch	Powdery mildew	Take all
Cereals	5-10 *	Snow mould Common bunt Covered smut		Loose smut Leaf stripe
Potatoes	100-200	Early blight	Late blight	
Vegetables	100-200	Leaf spots	Downy mildew	
Coffee	75-100	Rust		

* g a.i./100 kg seed

Numerous field trials were carried out from 1998 to 2001 in order to establish the optimum use pattern for HEC5725 in cereals. Most of the trials summarised in Table 2–6 were conducted in compliance with approved guidelines (EPPO - European and Mediterranean Plant Protection Organisation or CEB - Commission Essais Biologiques, France) and with application timing according to common agricultural practice.

Wheat

In winter wheat, HEC5725 provides complete control of Septoria leaf spot diseases, caused by *Septoria tritici* and *Leptosphaeria nodorum*, including Septoria glume blotch. Rust diseases of wheat (*Puccinia recondita, P. striiformis*) are also well controlled, reaching or exceeding the performance of the best commercial standard products. Due to its rapid uptake and translocation into the leaf, HEC5725 allows a very flexible application timing, as can be seen from Table 3. An excellent control of *Septoria tritici* is provided not only in phases of growth early in the season, but also during the rapid growth of the canopy.

Barley

The performance of HEC5725 in winter barley is described in Table 4. *Rhynchosporium secalis*, which requires a fungicide with a strongly pronounced leaf systemicity for effective control, is very efficiently controlled by HEC5725, as are *Pyrenophora teres, Puccinia hordei* and *Blumeria graminis* f. sp. *hordei*. The level of control achieved reaches or surpasses

commercial strobilurin standards and provides complete protection against all important barley leaf diseases.

Table 2. Efficacy of HEC5725 against *Septoria tritici* (1998-2000), *Leptosphaeria nodorum* (1998-1999) and *Puccinia recondita* (1998-2000) in winter wheat

Treatment	Rate	Efficacy (% control)		
	(g a.i./ha)	*S. tritici* (18)	*L. nodorum* (6)	*P. recondita* (7)
HEC5725	200	88	82	96
Azoxystrobin	250	81	80	93
Untreated (% disease)	-	51	27	18

( ) = number of trials

Table 3. Efficacy of HEC5725 against *Septoria tritici* (1997-2000), dependent on application timing (according to BBCH-scale, Lancashire *et al.*, 1991) and number of sprays

Treatment	Rate		Efficacy (% control)			
	(g a.i./ha)	BBCH:	32-39 (7)	42-51 (11)	59-67 (5)	32-39/55-69 (18)
HEC5725	200		77	84	82	88
Azoxystrobin	250		75	70	79	81
Untreated (% disease)	-		40	70	51	51
		No. of sprays	1	1	1	2

( ) = number of trials

Table 4. Efficacy of HEC5725 against *Pyrenophora teres* (1998-2000) and *Rhynchosporium secalis* (1998-2000) in winter barley

Treatment	Rate	Efficacy (% control)	
	(g a.i./ha)	*P. teres* (20)	*R. secalis* (11)
HEC5725	200	91	90
Azoxystrobin	250	78	63
Untreated (% disease)	-	56	54

( ) = number of trials

HEC5725 in combination with prothioconazole

As a contribution to an anti-resistance management strategy for strobilurins, HEC5725 will be either developed as co-formulations or recommended as a tank-mix with fungicides from other chemical classes. In addition, this strategy provides opportunity for the efficacy of HEC5725 to be further stabilised and the spectrum of activity broadened, especially in wheat. As can be seen from Tables 5-6, prothioconazole (JAU6476), a new DMI fungicide from the chemical class of triazolinthiones (Mauler-Machnik *et al.*, 2002) will be an ideal partner for HEC5725,

providing at least additive effects and opening the spectrum of activity towards stem base and ear diseases such as *Pseudocercosporella herpotrichoides* and *Fusarium* ear blight.

Table 5. Efficacy of HEC5725 alone and in combination with prothioconazole against *Septoria tritici* (3 trials, Belgium 2000)

Treatment	Rate (g a.i./ha)	Efficacy (% control)
HEC5725	150	75
	200	77
Prothioconazole	150	75
	200	80
HEC5725+Prothioconazole	125+125	85
	150+150	85
Untreated (% disease)	-	71

Table 6. Efficacy and yield response of HEC5725 + prothioconazole towards *Fusarium* ear blight in winter wheat (1998-2001; 1 treatment at BBCH 60-71)

Treatment	Rate (g a.i./ha)	Efficacy (% control) (29)	Yield (%, relative) (27)
HEC5725+Prothioconazole	150+150	71	120
Tebuconazole	250	52	112
Untreated (% disease)	-	28	100 (= 7.2 t/ha)

( ) = number of trials

CONCLUSIONS

HEC5725 is a broad-spectrum fungicide with pronounced leaf-systemic activity from the chemical class dihydro-dioxazines, which equals or surpasses current commercial standard products for the control of cereal diseases. Its systemic mode of action offers a flexible application timing and optimal mixing partner strategies with other specific and broad-spectrum fungicides. HEC5725 is safe to the environment and crops at recommended rates of application.

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New in-furrow fungicides for seedling disease control in cotton

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ABSTRACT

Newly available in-furrow fungicides were field-tested in 1997-2001 for efficacy in controlling seedling disease in cotton. The new fungicides included: Quadris (azoxystrobin), Flint (trifloxystrobin), and Ridomil Gold (mefenoxam). The standard, older fungicides tested were: Terraclor Super X (quintozene + ethazol), Terrazole (ethazole), Ridomil (metalaxyl), Rovral (iprodione), and Terraclor (quintozene). Combinations of these fungicides were also tested.

Seedling survival and yield were significantly increased with almost all in-furrow treatments tested in 1997 and 2001. The new fungicides performed as well as, if not better than, the older standard fungicides. Trifloxystrobin + mefenoxam increased stand counts when tested in 1998 and 2000 over other standard fungicides. In 2001, azoxystrobin had higher stand counts than the standard quintozene/mefenoxam. Although yield was not significantly increased over standard fungicides, these two new strobilurin fungicides controlled significantly more seedling disease based on stand counts. A seed treatment with azoxystrobin also improved stand counts over other standard hopper box treatments in 2001. Although disease conditions were less severe in 1998-2000, almost all in-furrow fungicides increased yield over the untreated control, except for the test in 1998.

INTRODUCTION

Seedling disease in cotton is a worldwide problem, often causing serious stand loss where it is not controlled (Hillocks, 1992). In the USA, it is the number one disease problem for many producers, especially in colder soils on the northern edge of the cotton-growing region. During the period 1997-2001, USA cotton producers lost an average of 2.9 percent (584,000 bales) each year to seedling disease. In Tennessee, late April and early May are prime planting dates, but this time usually brings cold, wet weather. As a result, Tennessee has the highest loss from seedling disease, averaging 6.8 percent (55,000 bales) annually with a high of 9.5 percent loss in 1997 (Blasingame, 2001).

Seedling disease is caused by a complex of seed-borne and soil-borne fungi and bacteria. The most common seedling disease pathogens include *Rhizoctonia solani*, *Pythium* spp., *Thielaviopsis basicola* and several *Fusarium* spp. Symptoms of seedling disease include seed rots and pre-emergence and post-emergence damping-off and occurs wherever cotton is grown (Kirkpatrick & Rothrock, 2001). *Pythium* spp. are the most frequent cause of pre-emergence damping-off, and *R. solani* is the most common cause of post-emergence damping-off.

The fungicides that have historically been effective in reducing *R. solani* in cotton seedling disease are quintozene, chloroneb and iprodione. Recent fungicides that have shown efficacy

against *R. solani* are azoxystrobin and trifloxystrobin. *Pythium* spp. have successfully been controlled with metalaxyl and ethazol. Newer formulations with mefenoxam have given a high level of control. Our objective in this five-year study was to compare the efficacy of the newer fungicides to the older, standard in-furrow fungicides for controlling seedling disease.

MATERIALS AND METHODS

Field experiments were conducted each year during 1997-2001 on a falaya silt loam soil under no-till conditions near Jackson, Tennessee. Each treatment was four rows spaced 96.5 cm apart and 9.13 m in length with four replications in a randomized complete block design with 10-13 seeds m^{-1}. The centre two rows were inoculated in the furrow with *R. solani* and *Pythium* spp. grown on millet seed to aid in uniformity of disease development. All fungicide treatments were placed in-furrow 2.5 cm deep along with the seed at planting time. There was no mixing of the fungicides with the soil because of the no-till planting method. All data were collected from these two center rows. Planting dates varied according to temperature and moisture conditions. They were: May 1, 1997; May 5, 1998; April 21, 1999; May 1, 2000; and April 20, 2001. Varieties planted in these tests included Deltapine 50, 428B, 474, and 451 B/RR in 1997, 1998, 1999, 2000-01 respectively. Data were subjected to statistical analysis using Duncan's New MRT in the Pesticide Research Manager Computer Program produced by Gylling Data Management, Inc.

RESULTS

The results of the two in-furrow fungicide trials in 1997 are located in Tables 1 and 2. Mefenoxam was used in combination with quintozene in both liquid and granular formulations and compared to quintozene/ethazol in both liquid and granular formulations (Table 1). The data show that both combinations increased stand count and yield; however, iprodione + mefenoxam did not increase yield and stand as much. Azoxystrobin at two rates was compared with quintozene, metalaxyl and quintozene + metalaxyl (Table 2). Azoxystrobin at 144 g a.i. ha^{-1} numerically had the highest yield and stand count, but yield was not significantly different from other fungicides in the test. In 1998, trifloxystrobin was tested against quintozene/mefenoxam, azoxystrobin + mefenoxam, and quintozene/ethazol (Table 3). Although it produced the highest yield and stand count, yield was not significantly different from the other treatments in the test. The efficacy of a biological material (*Bacillus subtilis* strain GB49) was tested in 1999 at two in-furrow rates in combination with quintozene/ethazol (Table 4). It was found that, even at the highest rate, the biological material had little effect on yield or stand count. The results from 2000 (Table 5) show that trifloxystrobin, combined with mefenoxam increased stand count and yield, although it was not rate responsive. Azoxystrobin did not significantly increase stand count or yield in this test. The efficacy of in-furrow fungicides over hopper-box and additional seed treatments was demonstrated in 2001 (Table 6). In-furrow applications of azoxystrobin and quintozene/mefenoxam both significantly increased stand count but not yield over hopper-box and extra seed treatments; however, yields were increased over the control.

Table 1. Efficacy of mefenoxam for cotton seedling disease control in 1997

Fungicide (in-furrow)	Form	Concentration	Dose (g a.i. ha $^{-1}$)	Plants/18.3 m^{-1} 6-6-97	Yield, Lint (kg ha $^{-1}$)
Quintozene/	GR	100 g a.i.kg^{-1}	785		
mefenoxam	GR	5.0 g a.i.kg^{-1}	39	121 a	1466 a
Mefenoxam +	EC	479 g a.i.litre^{-1}	35		
quintozene	EC	240 g a.i.litre^{-1}	784	118 a	1432 a
Quintozene/	EC	240 g a.i.litre^{-1}	840		
ethazol	EC	60 g a.i.litre^{-1}	210	124 a	1397 a
Quintozene/	GR	150 g a.i.kg^{-1}	894		
ethazol	GR	38 g a.i.kg^{-1}	227	115 a	1357 a
Iprodione +	F	479 g a.i.litre^{-1}	168		
mefenoxam	EC	479 g a.i.litre^{-1}	35	73 b	1285 ab
Control	-	-	-	45 c	1135 b

Means followed by the same letter do not significantly differ (P=0.05, Duncan's New MRT). GR = granular; EC = emulsifiable concentrate; F = flowable; (+) = tank mixed; (/) = formulated mixture.

Table 2. Efficacy of azoxystrobin for control of cotton seedling disease in 1997

Fungicide (in-furrow)	Form	Concentration (g a.i. litre^{-1})	Dose (g a.i. ha $^{-1}$)	Plants/18.3 m^{-1} 6-6-97	Yield, Lint (kg ha $^{-1}$)
Azoxystrobin	F	249	144	132 a	1340 a
Azoxystrobin	F	249	96	126 ab	1161 a
Quintozene	EC	240	1784	127 ab	1267 a
Metalaxyl	EC	240	120	105 b	1232 a
Quintozene +	EC	240	1784		
metalaxyl	EC	240	120	119 ab	1161 a
Control	-	-	-	56 c	920 b

Means followed by the same letter do not significantly differ (P=0.05, Duncan's New MRT). F = flowable; EC = emulsifiable concentrate; (+) = tank mixed.

Table 3. Efficacy of trifloxystrobin for control of cotton seedling disease in 1998

Fungicide (in-furrow)	Form	Concentration	Dose (g a.i.ha^{-1})	Plants/18.3 m^{-1} 18-9-98	Yield, Lint (kg ha^{-1})
Trifloxystrobin +	WP	499 g a.i. kg^{-1}	196		
mefenoxam	WP	479 g a.i. kg^{-1}	86	174 a	975 a
Quintozene/	GR	100 g a.i. kg^{-1}	785		
mefenoxam	GR	5.0 g a.i. kg	39	136 b	965 a
Mefenoxam +	WP	449 g a.i. kg^{-1}	86		
azoxystrobin	SC	249 g a.i. litre^{-1}	96	142 b	875 a
Quintozene/	GR	150 g a.i. kg^{-1}	925		
ethazol	GR	38 g a.i. kg^{-1}	234	142 b	779 a
Control	-	-	-	135 b	870 a

Means followed by the same letter do not significantly differ (P=0.05, Duncan's New MRT). GR = granular; F = flowable; WP = wettable powder; (+) = tank mixed; (/) = formulated mixture.

Table 4. Efficacy of quintozene/ethazol with a biological material for cotton seedling disease control in 1999

Fungicide (in-furrow)	Form	Concentration (g a.i. kg^{-1})	Dose (g a.i. ha^{-1})	Plants/18.3 m^{-1} 24-9-99	Yield, Lint (kg ha^{-1})
Quintozene/	GR	150	925		
ethazol/	GR	38	234	115 a	1809 a
GB49					
Quintozene/	GR	150	1244		
ethazol/	GR	38	315	84 ab	1619 a
GB49					
Quintozene/	GR	150	1176		
ethazol	GR	38	298	98 ab	1569 a
Control	-	-	-	72 b	1330 b

Means followed by the same letter do not significantly differ (P=0.05, Duncan's New MRT). GR = granular; (/) = formulated mixture; GB49 = *Bacillus subtilis* strain GB49.

Table 5. Efficacy of trifloxystrobin for control of cotton seedling disease in 2000

Fungicide (in-furrow)	Form	Concentration (g a.i. litre^{-1})	Dose (g a.i. ha^{-1})	Plants/18.3 m^{-1} 19-6-00	Yield, Lint (kg ha^{-1})
Trifloxystrobin +	WP	499	122		
mefenoxam	EC	479	44	147 ab	1130 a
Trifloxystrobin +	WP	499	157		
mefenoxam	EC	479	44	153 a	1127a
Trifloxystrobin +	WP	499	175		
mefenoxam	EC	479	44	140 ab	1109 a
Azoxystrobin	F	249	140	129 bc	1066 ab
Control	-	-	-	116 c	976 b

Means followed by the same letter do not significantly differ (P=0.05, Duncan's New MRT). WP = wettable powder; F = flowable; EC = emulsifiable concentrate; (+) = tank mixed; (/) = formulated mixture.

Table 6. Efficacy of in-furrow applied fungicides, hopper-box, and overcoat seed treatments or cotton seedling disease control in 2001

Fungicide (in-furrow)	Form	App. meth.	Concentration	Dose (g a.i.ha^{-1})	Plants/18.3 m^{-1} 4-6-01	Lint kg ha^{-1}
Azoxystrobin	F	IF	249 g ai.litre^{-1}	140 g a.i. ha^{-1}	136 a	1021 a
Quintozene/	GR	IF	100 g a.i. kg^{-1}	785 g a.i.ha^{-1}		
mefenoxam	GR	IF	5.0 g a.i. kg^{-1}	39 g a.i. ha^{-1}	110 b	976 ab
Azoxystrobin	F	ST	249g a.i.litre^{-1}	2.4 ml a.i. kg^{-1} (seed)	83 c	916 abc
Quintozene/	D	HB	166 g a.i kg^{-1}	1.25 g a.i.kg^{-1}		
metalaxyl/	D	HB	42 g a.i. kg^{-1}	0.32 g a.i.kg^{-1}		
Bacillus subtilis GB03	D	HB	2.0 x 10^{9} spores g^{-1}	(seed)	58 d	835 bc
Metalaxyl/	F	HB	35 g a.i.kg^{-1}	0.31 g a.i.kg^{-1}		
chloroneb	F	HB	299 g a.i. kg^{-1}	2.7 g a.i. kg^{-1} (seed)	52 d	810 c
Control	-	-	-	-	33 e	629 d

Means followed by the same letter do not significantly differ (P=0.05, Duncan's New MRT). IF = In-furrow; ST = Seed treatment; HB = Hopper-box; GR = granular; D = dust; F = flowable; (+) = tank mixed; (/) = formulated mixture.

CONCLUSIONS

The data indicates that the newer in-furrow fungicides such as azoxystrobin and trifloxystrobin reduce seedling disease and increase stand count just as well as, or better than, the older fungicides. Addition of a biological material to quintozene/ethazol did not improve the yield or stand count. However, azoxystrobin as a seed treatment increased the stand count over standard hopper box treatments. Hopper-box and overcoat seed treatments are usually effective in lighter disease situations, yet 2001 was a severe seedling disease year. In-furrow soil treatments provide much more fungicide and root protection for the cotton seedling.

Cotton producers in the USA must strive to reduce inputs as much as possible due to the low prices for cotton in today's world markets. However, they must not cut inputs for in-furrow fungicides. Doing that would significantly increase seedling disease and thus decrease stand, yield and profit. Cotton producers will benefit from the use of strobilurin fungicides such as azoxystrobin and trifloxystrobin because they are very active on *Rhizoctonia*, the most damaging of all the seedling disease fungi. Azoxystrobin and mefenoxam are now approved for use in the USA and are commercially available (Newman, 2002). While fairly effective at various rates, trifloxystrobin has not yet been approved for use in the USA for in-furrow application in cotton.

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Ethaboxam: a new Oomycetes fungicide

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ABSTRACT

Ethaboxam is a new aminothiazole carboxamide fungicide to control diseases caused by Oomycetes. Target diseases are grape downy mildew caused by *Plasmopara viticola* and potato late blight caused by *Phytophthora infestans*. In addition, ethaboxam can be applied to various Oomycetes diseases on other crops including, cucumber, hop, lettuce, onion, pea, pepper, sesame and tomato. Ethaboxam has intrinsically outstanding preventive, curative, translaminar and systemic activity. It is highly inhibitory to the mycelial growth and sporulation of *P. infestans* and other pathogens. There has been no report of resistance to ethaboxam; the fungicide is highly inhibitory to the growth of isolates that are resistant to phenylamide and strobilurin fungicides.

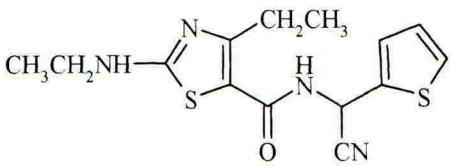
INTRODUCTION

Ethaboxam was discovered and developed by LG Life Sciences Ltd., formerly LG Chem Ltd. (Ra *et al.*, 1995). The fungicidal activity of ethaboxam is highly specific to the Oomycete group of fungi, the cause of various diseases in many crops (Kim *et al.*, 1999). A wettable powder formulation (25% WP) is commercialized with the trade name Guardian® in Korea, and several formulations in straight or co-formulated mixture products are now in the process of commercial development. This study reports the chemical, physical, toxicological and biological properties of ethaboxam studied to date.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name:	(RS)-N-(α-cyano-2-thienylmethyl)-4-ethyl-2-(ethylamino)-5-thiazolecarboxamide
ISO name:	Ethaboxam
Code number:	LGC-30473
CAS registration No.:	162650-77-3

Structural formula:



Molecular formula: $C_{14}H_{16}N_4OS_2$

Molecular weight:	320.7
Physical state:	White crystalline powder
Melting point:	Not determined, decomposed on melting at 185°C
Vapour pressure:	8.1×10^{-5} Pascal at 25°C
Partition coefficient:	Log Pow = 2.89 at pH 7
Water solubility:	4.8 mg/litre at 20°C

MAMMALIAN AND ENVIRONMENTAL SAFETY

Acute oral, rat, mouse (male/female):	> 5000 mg/kg
Acute dermal, rat (male/female):	> 5000 mg/kg
Acute inhalation, rat (male/female):	> 4.89 mg/litre
Eye irritation, rabbit:	non-irritant
Skin irritation, rabbit:	non-irritant
Skin sensitisation, guinea pig:	non-sensitising
Mutagenicity (ames, micronucleus):	negative
Teratogenicity, rat, rabbit:	negative

Bluegill (*Lepomis macrochirus*):	LC_{50} >2.9 mg/litre (96 h)
Fathead minnow (*Pimephales promelas*):	LC_{50} >4.6 mg/litre (96 h)
Rainbow trout (*Salmo gairdneri*):	LC_{50} = 2.0 mg/litre (96 h)
Daphnia (*Moina macrocopa*):	EC_{50} = 0.33 mg/litre (48 h)
Algae (*Selenastrum capricornutum*):	EC_{50} >3.6 mg/litre (120 h)
Honeybee (*Apis melifera*):	LD_{50} >100 µg ai/bee
Earthworm (*Eisenia foetida*):	LD_{50} >1000 ppm
Bobwhite quail:	LD_{50} >5000 mg/kg

BIOLOGICAL PROPERTIES

Fungicidal spectrum

Ethaboxam is specifically inhibitory to the growth of pathogens belonging to the class Oomycetes (Table 1). Ethaboxam was not inhibitory at all when tested against *Rhizoctonia solani, Botrytis cinerea, Magnaporthe grisea, Penicillium italicum, Cercospora beticola, Diaporthe citri, Alternaria alternata* or *Gibberella fujikuroi*.

Table 1. Fungicidal spectrum of ethaboxam

MIC (mg/litre)	Species
0.1-1.0	*Phytophthora infestans, Pseudoperonospora cubensis*
1.1-10.0	*Phytophthora capsici, Plasmopara viticola, Pythium ultimum*
11.1-100	*Pythium graminicola*
> 100	*Pythium aphanidermatum, Cladosporium resinae, Corynespora cassiicola*

Mode of action

Ethaboxam specifically inhibits mycelial growth and sporulation of *P. infestans* (Table 2). Interestingly, it has almost no activity on the germination of sporangia and cysts and on the motility of zoospores. This mode of action is different from other fungicides in this class. Efforts to elucidate its biochemical action mechanism are currently in progress.

Table 2. Inhibitory activity of ethaboxam during the life cycle of *P. infestans*

Dose (mg/litre)	Inhibitory activity (%)				
	Sporangium germination	Zoospore Motility	Cyst germination	Mycelial growth	Sporulation
0.01	0	0	0	25	69
0.1	0	0	0	100	98
1.0	0	0	0	100	99

Resistance and cross resistance

Repeated tests to induce mutants resistant to ethaboxam by UV irradiation and the mutagen NMNG were not successful with *P. infestans* and *P. capsici*. As a contribution to baseline monitoring for resistance management, the MIC was determined for populations of *P. viticola* in France. The MICs ranged 0.1-10.0 mg/litre with the highest population between 0.3-3.0 mg/litre. All of the nine isolates of *P. infestans* resistant to metalaxyl (MIC >100 mg/litre) and eight isolates of *P. capsici* resistant to metalaxyl (MIC >200 mg/litre) were susceptible to ethaboxam with MIC values ranging from 0.1 to 5.0 mg/litre. Recently, resistance to strobilurin fungicides has become an important issue in the management of fungicide resistance in many countries (Fuji *et al.*, 2000). One isolate of *Pseudoperonospora cubensis* resistant to kresoxim-methyl was tested and found to be highly sensitive to ethaboxam. These results indicate that ethaboxam products can be effectively used for management of resistance to phenylamides and strobilurins.

Field tests

The field performance of ethaboxam formulated as a 10% SC has been extensively evaluated against grape downy mildew in Europe in 2001. When used as a foliar spray at 7-10 day intervals in field conditions, ethaboxam effectively controlled grape downy mildew on both leaves and bunches at application rates of 100-250 g a.i./ha (Table 3). Similar activity was observed in other field tests (Figure 1). Although ethaboxam was highly effective at 100-150 g a.i./ha in some trials, the results varied with location and disease pressure. Therefore, the optimum application rate in this formulation was determined as 200 g a.i./ha for potato late blight. At this application rate, high anti-sporulation and moderate systemic activities were consistently observed throughout the trials

Table 3. Fungicidal activity of ethaboxam against grape downy mildew (France, 2001)

Treatment	Dose (g a.i./ha)	Infected leaf area (%)			Infected bunch area (%)	
		7 DAT5 (BBCH75)	3 DAT8 (BBCH77)	3 DAT10 (BBCH83)	3 DAT8 (BBCH77)	3 DAT10 (BBCH83)
None	-	17.9	35.6	48.9	30.4	53.3
Ethaboxam	100	2.0	4.1	8.6	1.4	4.7
	150	1.0	1.9	4.3	1.2	3.3
	200	0.3	0.5	2.2	0.5	0.6
	250	0.2	0.0	1.7	0.3	3.6
Mancozeb	1600	3.1	10.0	8.7	4.7	10.3
Cymoxanil +mancozeb	120 +1395	1.1	6.4	6.8	2.0	9.5

Cultivar: Chardonnay; location: Orleans, Loiret, France.
Application interval: 7-10 days; spray volume: 640-944 litre/ha.

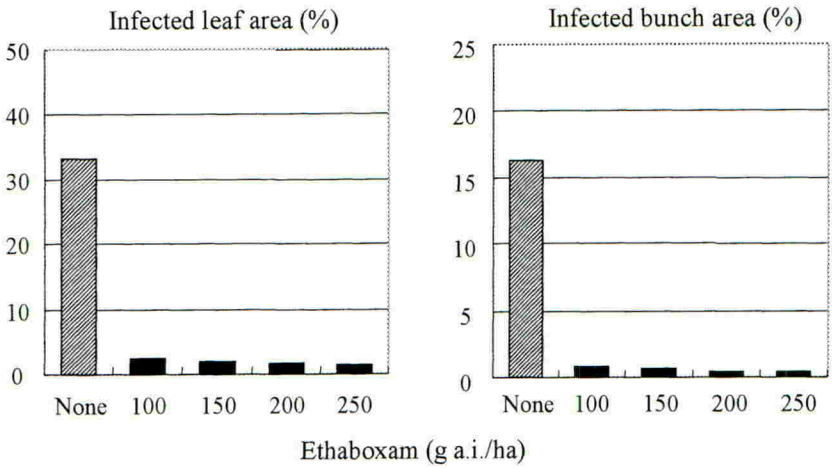


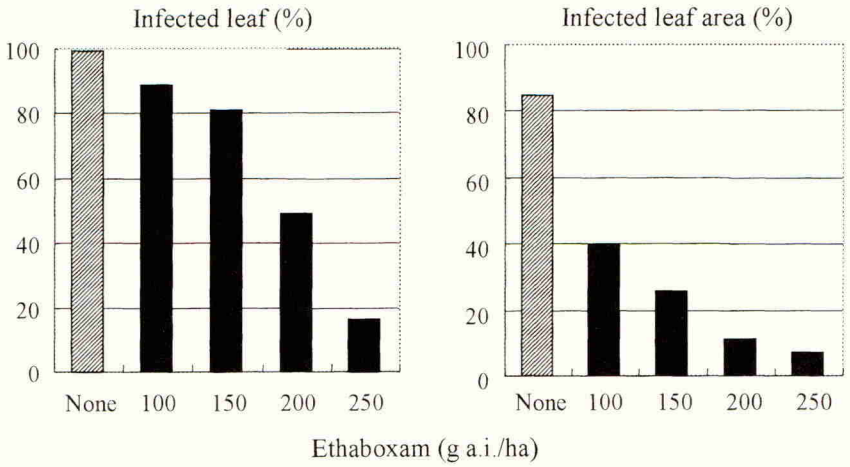
Figure 1. Summary of fungicidal activity of ethaboxam against grape downy mildew from 12 field trials in Europe (2001)

Ethaboxam formulated into a 25% WP was also tested against potato late blight in field conditions. When applied to leaves at 7-10 day intervals, ethaboxam in this formulation resulted in good efficacies at application rates of 150-250 g a.i./ha (Table 4). Under extremely high disease pressure, potato late blight kept increasing with the repeated applications at 250 g a.i./ha, although control was equivalent to the commercial standard product. Similar efficacies were observed other field tests. In repeated field tests, application at 100 g a.i./ha showed weak efficacy, whilst treatment at 150-200 g a.i./ha resulted in some variable efficacies under different environment conditions (Figure 2). Therefore, the optimum application was recommended at 250 g ai/ha for control of potato late blight with this formulation. Under high disease pressure, products co-formulated with other fungicides are in consideration because of its reduced efficacy against potato late blight in these situations.

Table 4. Fungicidal activity of ethaboxam against potato late blight (UK, 2000)

Treatment	Dose (g a.i./ha)	Infected leaf area (%) 7/7 (9 DAT1)	14/7 (6 DAT2)	24/7 (7 DAT3)	2/8 (7 DAT4)	12/8 (7 DAT5)	22/8 (6 DAT6)
None	-	1.0	23.5	49.5	82.0	96.5	100.0
Ethaboxam	100	0.5	4.0	3.7	7.0	16.7	70.5
	150	0.3	3.5	3.5	6.3	9.7	34.0
	200	0.0	2.3	2.0	5.0	9.5	29.7
	250	0.2	1.7	1.5	3.5	6.7	21.0
Dimethomorph +mancozeb	150 +1334	0.2	4.5	4.0	8.2	11.2	25.7

Cultivar: King Edward; location: Talbenny, Pembrokeshire, UK,
Application interval: 7-10 days; spray volume: 300 litre/ha.



Application interval: 7-10 days; spray volume: 200-400 litre/ha.

Figure 2. Summary of fungicidal activity of ethaboxam against potato late blight after final assessment from eight field trials in Europe (1999-2000)

DISCUSSION

Ethaboxam is safe with regard to mammalian and environmental toxicities. Biologically, ethaboxam is highly effective against mycelial growth and sporulation of *P. infestans*. From the viewpoint of resistance management, ethaboxam may have a high potential to replace, or be an alternative for use with, other Oomycete fungicides, because we have found no resistance or cross-resistance throughout the studies. The results of extensive field tests

by *P. viticola* at 200 g a.i./ha and potato late blight caused by *P. infestans* at 250 g ai/ha using foliar applications at 7-10 day intervals.

ACKNOWLEDGEMENTS

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Disease control with a yeast elicitor in conjunction with fungicides

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ABSTRACT

Inducing systemic plant resistance is a promising approach to improving plant protection which can enhance the effectiveness of conventional fungicide programmes. The objective of these trials was to determine whether a yeast extract, in conjunction with applications of either strobilurin or triazole fungicides, enhances the control of *Phytophthora infestans* in potatoes and tomatoes, *Pseudomonas syringae* in *tomato*, and *Uncinula necator* in grapes. All crops received two applications of a yeast extract, alternating with two applications of either a strobilurin or a triazole fungicide. Controls received the standard four applications of fungicide. In all trials, alternating the yeast extract with either strobilurin or a triazole fungicide reduced fungal disease in grapes, potatoes and tomaotes equally when compared with the standard four applications of the fungicide. Yields were increased in tomatoes. These results indicate that the yeast extract has potential to increase the effectiveness of conventional fungicide programmes.

INTRODUCTION

Induced systemic resistance (ISR) is a phenomenon whereby resistance to infectious disease is systemically induced by localized infection or treatment with microbial components or products or by a diverse group of structurally unrelated inorganic or organic compounds. ISR is most effective against fungi (Kuć, 2000). The yeast component used here was derived from *Saccharomyces cerevisiae* and consisted primarily of mannan-oligosaccharides (Lyons, 1970). It belongs to a new category of systemic inducers known as plant activators. Preliminary studies indicate it has two modes of action (Newton *et al.*, 1993). The first is that a thin film of mannan-oligosaccharides is deposited on the leaves and stems of the crop and prevents attachment of the pathogen to the plant tissue. The second, and more important means, is through the development of ISR after it has been taken into the crop plant. By application of this yeast extract, the expectation is that the crop plant is stimulated into a high state of preparedness and will be better able to defend itself against pathogenic invasions.

There are two conditions that need to be met for this technology to be successful. The first is that systemic resistance is induced well in advance of invasion. The second is that once the systemic resistance has been induced, it must be maintained at a high level during the period that disease prevention is desired. This is normally accomplished by the periodic application of the elicitor. At a biochemical level, peroxidase expression has been shown in several plant systems to be altered by stress chemicals and infection and may be used to indicate activation of ISR (Lagrimini *et al.*, 1993).

The objectives of the work described here were to use the yeast extract to improve fungicide efficacy and to obtain better disease control with reduced use of fungicides. Variation in peroxidase activity was determined as a measure of ISR.

MATERIALS AND METHODS

The materials used in both greenhouse and field studies are given in Table 1.

Table 1. Plant protection products and their rate of use

Products	Active material	Type of action	Dosage of product (in 1,000 litre water/ha)
ISR 2000	Yeast extract 300 mg/l + *Yucca schidigera* plant extract 10%	Plant activator	900 ml
Crop-Set	Yeast and plant extracts	Bio-stimulant	600 ml
Experimental	Fenamidon + mancozeb	Fungicide	200 g
Quadris	Azoxystrobin (250 g/litre)	Fungicide	750 ml
Cupracol	Copper oxychloride (500 g/litre)	Fungicide + bactericide	2 litre
Champion	Copper hydroxide (770 g/litre)	Fungicide + bactericide	2.5 kg
Shavit	Triadimenol (250 g/litre)	Fungicide	100 ml

Greenhouse tests

Tomato seedlings were grown in pots under greenhouse conditions (25±2 °C, 8/16h photoperiod). To test the elicitation response and the level of disease resistance, plants were treated at the 8-10 leaf stage with the yeast extract, fungicides and bactericides or just water (control). Treatments were applied three times at seven day intervals. Pathogens tested were late blight (*Phytophthora infestans*) and bacterial speck (*Pseudomonas syringae* pv. *tomato*). These were applied 3 days after the first application of yeast extract or chemical, and leaves were collected for peroxidase assay 10 days after the last applications. Fifteen replications were carried out per treatment.

Leaves were harvested, freeze-dried in liquid nitrogen and lyophilized. Crude extracts (0.2 g) were homogenized with 2 ml sodium phosphate buffer (0.05 M, pH 6.5) and centrifuged. The supernatants were collected and their protein concentrations were determined (Bradford, 1976) using bovine serum albumin as a standard. The peroxidase enzyme activity was assayed spectrophotometrically (Kanner & Kinsella, 1983).

Field tests

Two field trials were conducted in 2000 in drip-irrigated tomato crops in the research fields of Demko, one of the largest tomato processors in Turkey. Plots contained approximately 250 plants and treatments were replicated four times in a randomised complete block design. The yeast extract was applied twice at 1 litre/ha in 1,000 litres water/ha at 2 and 5 weeks after transplanting. As a grower standard treatment for comparison, copper hydroxide was applied

once at seedling stage and copper oxychloride was sprayed at the same time as the yeast extract. Plots (3 m) were evaluated for fruit number on 27 June 2000, and harvested on 13 August 2000. The trial field of Demko suffered from a lack of water due to damage to the drip irrigation system for several weeks during the growing season. There were no quantifiable diseases in the fields possibly because of the very dry conditions.

In 2001, field trials on blight in tomatoes and potatoes were conducted at two locations. Experiments were of a randomised block design with four replications; each block was 6 rows wide and 10 m long. Products were applied at label recommended rates using a back-pack sprayer. First application was made when conditions were conducive for the disease, around first bloom, and continued at 10 day-intervals. Treatments were evaluated using a 0-5 severity scale, on 60-75 plants from the middle 4 rows in each plot, when the first fruits reached the harvest stage for tomatoes and 10 days after the last application for potatoes.

Trials on grapevine powdery mildew were carried out using a randomised block design with 5 replicates. Each replicate consisted of 16 vines (4x4). A back-pack sprayer was used for thorough spray coverage. Sprays began when the shoots were about 25-30 cm length, in April for Ege region and in May for Marmara region. Second treatments were applied at the time flower petals dropped and berries were forming; the following sprays were applied every 2 weeks. Severity of powdery mildew (0-3 scale) was assessed on 100 leaves from the four vine stocks, beginning with the fourth leaf from the bottom.

RESULTS AND DISCUSSION

Enzyme activity

Peroxidase enzyme activities in tomato leaves were increased greatly after treatment with the yeast extract. When treatment was followed by inoculation with *Pseudomonas syringae* pv. *tomato* and copper oxychloride, or *Phytophthora infestans* and yeast extract with plant extracts, there were also large increases in peroxidase activity compared with the control (Table 2).

Table 2. Peroxidase enzyme activity in tomato leaves following treatment with a yeast extract and challenge with *Phytophthora infestans* and *Pseudomonas syringae* pv. *tomato*

Treatment	Mean±SE mg/ml/minute	Effect %
Control (water only)	165±13.5	100
Yeast extract	600±35.2	264
Yeast extract + *Phytophthora infestans* + yeast with plant extracts	374±15.3	127
Yeast extract + *Phytophthora infestans* + fenamidon and mancozeb	175±14.5	30
Yeast extract + *Pseudomonas syringae* pv *tomato*	168±11.2	2
Yeast extract + *Pseudomonas syringae* pv *tomato* + copper oxychloride	795±38.2	382

In greenhouse trials on tomato late blight, the greatest effectiveness was found with the yeast extract + fenamidon and mancozeb (80% reduction) (Table 2). The yeast extract + copper hydroxide gave the greatest reduction of bacterial speck (Table 3). The yeast extract alone

was comparably effective against both diseases. These results show that, under greenhouse conditions, alternating a chemical treatment (one spray) with a yeast extract (two sprays) was equivalent to the chemical treatment alone (three sprays).

Table 3. Effect of a yeast extract and fungicides on tomato late blight (*P. infestans*)

Treatment	No of sprays	Disease severity (%)	Efficacy (%)
Control (water only)	3	61.4	-
Yeast extract	3	19.6	68.0
Yeast extract + fenamidon and mancozeb	2+1	12.4	80.0
Yeast extract + azoxystrobin	2+1	13.8	78.0
Yeast extract + mancozeb	2+1	15.3	75.0
Azoxystrobin	3	16.6	73.0

Table 4. Effect of a yeast extract and fungicides on bacterial speck (*P. syringae* pv. *tomato*)

Treatment	No of sprays	Mean number of spots	Efficacy (%)
Control (water only)	3	27.1	-
Yeast extract	3	8.6	68.3
Yeast extract + copper hydroxide	2+1	2.5	85.0
Yeast extract + copper oxychloride	2+1	3.0	88.9
Copper hydroxide	3	5.5	79.7
Copper oxychloride	3	5.8	78.6

Field trials

In the tomato field trials in 2000, no foliar disease was observed at either site. Nevertheless, at 7 weeks before harvest, plants treated with the yeast extract had significantly more flowers and fruit than the grower standard (Table 5). Under the stress conditions related to the water shortage, plants treated with the yeast extract yielded significantly more tomatoes, and a larger percentage of red marketable fruit, than those treated with the grower standard fungicides (Table 6).

Table 5. Effect of yeast extract and fungicides on the number of open flowers and set tomato fruit, Turkey 2000

Treatment	No. of sprays	Total number fruit + flowers	
		Site 1	Site 2
Yeast extract	2	63.0	32.2
Fungicide	3	38.2	26.9
T-Test		P=0.01	P=0.02

Table 6. Total weight (kg) of tomatoes following treatment with yeast extract or fungicides, Turkey, 2000

Treatment	No. of sprays	Total yield (kg)	
		Site 1	Site 2
Yeast extract	2	37.3	32.2
Fungicides	3	20.5	26.9
Students T-Test		P=0.01	P=0.02

In tomato field tests in 2001, the severity of late blight averaged 37.8% (leaf area affected) and the efficiency of the yeast extract, when used in alternation with azoxystrobin, was found to be 87.4%. Azoxystrobin alone showed 87.7% efficacy. There were no statistically significant differences between either the yeast extract + azoxystrobin treatment and azoxystrobin alone (Table 7). No phytotoxicity was observed following treatment with the yeast extract.

Table 7. Effect of yeast extract and fungicides on tomato late blight (Aegean and Marmara Region), 2001

Treatment	No of sprays	% blight control	
		Aegean	Marmara
Yeast extract	4	65.8	68.3
Yeast extract + azoxystrobin	2+2	88.3	87.4
Azoxystrobin	4	88.1	87.7

In potato field trials, similar results were obtained. Alternating the yeast extract and azoxystrobin gave 87.4% control, equivalent to that achieved with azoxystrobin alone (Table 8). The use of the yeast extract alternating with azoxystrobin proved to be effective in decreasing the number of fungicide applications necessary when disease severity was medium. Yeast extract alone also gave some control of potato blight, althogh it was not as effective as the other treatments.

Table 8. Effect of yeast extract and azoxystrobin on potato late blight (Aegean and Marmara Region), 2001

Treatment	No of sprays	% blight control	
		Aegean	Marmara
Yeast extract	4	68.4	68.3
Yeast extract + azoxystrobin	2+2	87.7	87.2
Azoxystrobin	4	88.0	87.5

In vineyard tests, yeast extract alternating with triadimenol was found to be as effective as triadimenol alone in the control of powdery mildew in grapes (Table 9). Yeast extract alone also gave some control.

Table 9. Effect of yeast extract and triadimenol on grape powdery mildew (Aegean and Marmara Region), 2001

Treatment	No of sprays	% control of powdery mildew			
		Aegean		Marmara	
		Leaves	Bunches	Leaves	Bunches
Yeast extract	4	60.7	63.3	65.1	63.3
Yeast extract + triadimenol	2+2	85.2	95.7	84.6	95.6
Triadimenol	4	88.7	96.0	87.1	96.9

In summary, the use of a yeast extract in integrated disease management is environmentally friendly and can help reduce the number of fungicides required to achieve effective control. It may also reduce the cost of disease control and the likelihood of resistance development.

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JAU 6476 – a new dimension DMI fungicide

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ABSTRACT

JAU 6476 is a novel broad-spectrum fungicide. It belongs to the new chemical class of triazolinthiones discovered and developed by Bayer AG. The common name for this molecule is prothioconazole. JAU 6476 is a systemic fungicide showing excellent efficacy against a broad range of diseases in different crops. In wheat and barley this new dimension DMI fungicide provides outstanding control of eyespot (*Pseudocercosporella herpotrichoides*), Fusarium ear blight (*Fusarium* spp., *Microdochium nivale*), leaf blotch diseases (*Septoria tritici, Leptosphaeria nodorum*, *Pyrenophora* spp., *Rhynchosporium secalis* etc.), rust (*Puccinia* spp.) and powdery mildew (*Blumeria graminis*). JAU 6476 can be applied as a straight product and is also an ideal mixing partner for other compounds. Applied as a seed treatment, JAU 6476 shows very good activity against important seed- and soilborne diseases (*Ustilago* spp., *Tilletia* spp., *Fusarium* spp., *Microdochium nivale*). Prothioconazole combines excellent activity, crop safety and a favourable toxicological and environmental profile with an overall excellent technical performance to guarantee high quality yields.

INTRODUCTION

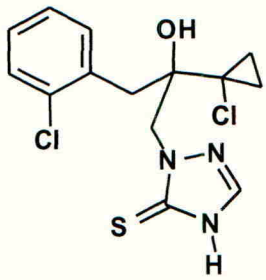
Azoles are the largest and most important class of fungicides over the last 30 years. Bayer has a long experience with this chemical class, commercialising the first azole, triadimefon, followed by several compounds of further generations of azoles (Kuck *et al.*, 1995).

JAU 6476 is the success of an innovative synthesis programme for the evolution of azole chemistry. It is the top-performer out of this project belonging to a new chemical class. The excellent technical performance of this compound has been determined extensively in laboratory, greenhouse and worldwide field trials. Market introduction is expected for the 2004 season with a main emphasis on cereals, oilseed rape, peanuts, rice and pulses. This paper describes its chemical and physical properties, its toxicological and environmental characteristics, the mode of action, the fungicidal spectrum and its performance in the field.

CHEMICAL AND PHYSICAL PROPERTIES

CAS number:	178928-70-6
Common name (accepted by ISO):	Prothioconazole
Chemical class:	Triazolinthione
Molecular formula:	$C_{14}H_{15}Cl_2N_3OS$

Structural formula:



Chemical name (IUPAC):	2-[2-(1-chlorocyclopropyl)-3-(2-chlorophenyl)-2-hydroxypropyl]-2,4-dihydro-3H-1,2,4-triazole-3-thione
Molecular weight:	344.27
Appearance:	white to light beige crystalline powder
Melting range:	139.1°C – 144.5°C
Vapour pressure:	<< 4 x 10^{-7} Pa at 20°C
Volatility:	<< 3 x 10^{-5} Pa.m^3/ mol (Henry's Law Constant)
Partition coefficient:	unbuffered 4.05 log Pow at 20°C
Solubility in water:	0.3 g/l at 20°C
Dissociation constant:	pKa = 6.9

TOXICOLOGICAL AND ECOTOXICOLOGICAL PROPERTIES

Acute oral LD_{50}, rat:	> 6200 mg/kg b.w.
Acute dermal LD_{50}, rat:	> 2000 mg/kg b.w.
Acute inhalation LC_{50}, rat:	> 4990 mg/m^3 air
Skin irritation, rabbit:	not irritating
Eye irritation, rabbit:	not irritating
Skin sensitisation, guinea pig:	not sensitising
Mutagenicity:	no genotoxic effects
Chronic toxicity:	no embryotoxic potential
Development toxicity:	no teratogenic potential
Bird, acute oral LD_{50}, quails:	> 2000 mg
Fish, acute, 96 h, LC_{50}, rainbow trout:	1.83 mg a.s./l
Daphnia magna acute, 48 h, EC_{50}	1.30 mg a.i./litre
Algae, chronic, 72 h, EC_{50}	2.18 mg a.i./litre
Earthworm, acute, 14d, LC_{50}	>1000 mg a.i./kg d.wt.s.
Honeybee, LC_{50}	not harmful
Non-target arthropods/soil organisms:	no effects

ENVIRONMENTAL FATE

Soil degradation/mobility:	Prothioconazole and its metabolites showed very low potential for leaching or accumulation

Prothioconazole has a favourable toxicological and ecotoxicological profile. It is safe to users and the environment.

MODE OF ACTION AND SYSTEMICITY

The compound shows ideal systemic properties. These provide protective, curative, eradicative and long-lasting activity by a balanced, uniform and stable distribution in the leaves. The mechanism of action of JAU 6476 is the inhibition of demethylation at position 14 of lanosterol or 24-methylene dihydrolanosterol, which are precursors of sterols in fungi. Consequently prothioconazole belongs to the demethylation inhibitors (DMIs). The compound is being developed and registered both as a solo formulation as well as with different mixing partners. HEC5725, a novel leaf-systemic strobilurin fungicide from Bayer CropScience (Dutzmann, *et al.*, 2002) will be an ideal partner for JAU 6476. Market introduction for both compounds is expected for the 2004 season. Effective ready-mix products with fungicides of chemical groups without cross resistance will offer a tool for preventative resistance management (Anon., 2001) and for adaptation to particular crop/disease situations.

BIOLOGICAL PROPERTIES

JAU 6476 shows excellent properties in wheat and barley. The compound was tested intensively for activity against major fungal pathogens in cereals. Field trials were conducted mainly in the UK, France and Germany. Trials were conducted according to EPPO (European and Mediterranean Plant Protection Organisation) guidelines, spray schedules according to common agricultural practice.

Wheat

Tables 1-4 give an overview of the broad activity of JAU 6476 against all important diseases of wheat. Stem base diseases (*Pseudocercosporella herpotrichoides, Rhizoctonia* spp., *Fusarium* spp., *Microdochium nivale*) (Table 1) are as well controlled as leaf blotch diseases (*Septoria tritici, Leptosphaeria nodorum, Pyrenophora tritici-repentis*) (Table 2), rust and powdery mildew (Table 3).

Table 1. Efficacy of JAU 6476 against *Pseudocercosporella herpotrichoides* and *Rhizoctonia cerealis* in wheat, France and Germany, 1997-1999

Treatment	Rate (g a.i./ha)	Efficacy (% control)	
		P. herpotrichoides (9)	*R.. cerealis* (3)
JAU 6476	200	65	66
Cyprodinil	750	58	25
Untreated (% disease)	-	54	31

( ) = number of trials

Table 2. Efficacy of JAU 6476 against *Septoria tritici*, *Leptosphaeria nodorum* and *Pyrenophora tritici-repentis* in wheat, France and Germany, 1998-2000

Treatment	Rate (g a.i./ha)	Efficacy (% control)		
		S. tritici (5)	*L. nodorum* (4)	*P. tritici-repentis* (6)
JAU 6476	200	83	84	80
Epoxiconazole	125	83	-	-
Tebuconazole	250	-	79	74
Untreated (% disease)	-	44	58	32

( ) = number of trials

Table 3. Efficacy of JAU 6476 against *Blumeria graminis* and *Puccinia recondita* in wheat, France and Germany, 1998-1999

Treatment	Rate (g a.i./ha)	Efficacy (% control)	
		B. graminis (5)	*P. recondita* (3)
JAU 6476	200	83	79
Cyprodinil	750	85	-
Epoxiconazole	125	-	85
Untreated (% disease)	-	13	20

( ) = number of trials

Table 4. Efficacy of JAU 6476 against *Fusarium* spp., *Microdochium nivale* and *Leptosphaeria nodorum* (ears) in wheat, UK, France and Germany, 1998-2000

Treatment	Rate (g a.i./ha)	Efficacy (% control)		
		Fusarium spp. (14)	*M. nivale* (3)	*L. nodorum* (3)
JAU 6476	200	68	76	80
Tebuconazole	250	57	48	78
Untreated (% disease)	-	35	19	39

( ) = number of trials

Additionally the compound provides excellent activity against ear diseases (*Fusarium* spp., *Microdochium nivale, Leptosphaeria nodorum*) (Table 4). The production of mycotoxins from *Fusarium* spp. of the *F. roseum*-type is effectively reduced. Prothioconazole gives full control of the whole spectrum of important fungal diseases. The excellent control of eyespot and ear diseases has to be pointed out in particular.

Barley

Under strong disease pressure (Table 5), *Pyrenophora teres* (net blotch) and *Rynchosporium secalis* (scald) are almost completely controlled. Besides fungicidal activity against net blotch, scald, powdery mildew and rust, prothioconazole controls damage caused by unspecific brown lesions (sun-burn, pollen scorch, *Ramularia collo-cygni* etc.).

Table 5. Efficacy of JAU 6476 against *Pyrenophora teres* and *Rhynchosporium secalis* in barley, France 1998-2000

Treatment	Rate (g a.i./ha)	Efficacy (% control)	
		P. teres (8)	*R. secalis* (11)
JAU 6476	200	92	94
Flusilazole + MBC	200 + 100	42	73
Untreated (% disease)	-	74	67

( ) = number of trials

Yield response

As a result of good crop safety and excellent disease control, significant yield increases are achieved following application of JAU 6476. The pure fungicidal activity is supported by plant physiological effects and controlled greening of the treated crops through an extended assimilation period.

Table 6. Yield responses of wheat and barley to JAU 6476, UK, France, Germany, 1998-2000

Treatment	Rate (g a.i./ha)	Relative yield		
		Fusarium spp. (ear) wheat (13)	*P. teres* barley (5)	*R. secalis* barley (7)
JAU 6476	200	134	144	130
Tebuconazole	250	120		
Flusilazole + MBC	200 + 100		117	120

( ) = number of trials

Other Crops

JAU 6476 gives an excellent efficacy not only in cereals, but also against a broad range of diseases in other crops. In oilseed rape and peanuts, the compound controls soilborne pathogens such as *Sclerotinia* spp. as well as all major leaf pathogens (*Leptosphaeria maculans*, *Pyrenopeziza brassicae*, *Cylindrosporium* spp., *Botrytis cinerea*, *Alternaria* spp., *Rhizoctonia* spp., *Mycosphaerella* spp., *Puccinia* spp. etc.).

CONCLUSIONS

JAU 6476 is a novel broad-spectrum fungicide which belongs to a new chemical class. It has a favourable toxicological and environmental profile. In wheat and barley this compound provides excellent control against all major pathogens and therefore is an innovative cornerstone for the production of high quality yields. The activity against stem base and ear diseases sets new standards. JAU 6476, straight or in mixtures, presents an unsurpassed performance within DMI fungicides.

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