SESSION 1

THE TWENTY-THIRD BAWDEN LECTURE

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Paper	1

THE FUTURE OF THE CAP AND THE IMPLICATIONS FOR CROP PROTECTION

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ABSTRACT

Domestic dissatisfaction with the Common Agricultural Policy (CAP) of the European Union (EU) centres around the effects of the imbalanced support it provides, the opportunities denied by supply management and the lack of legitimacy of the compensation payments. These pressures for reform are bolstered by the move to a more liberalised market inside the EU and internationally. It is generally agreed that the constraints imposed by the Uruguay Round Agreement on Agriculture (URAA) will bear increasingly during the next decade, and be intensified by a new World Trade Organisation (WTO) round starting in 1999 and by the inclusion of agriculture in regional free trade agreements. The application of the CAP to prospective new EU members in Central and Eastern Europe poses four problems: the high price regime, supply management, compensation payments, and living within the amalgamated URAA commitments. These problems both for the present EU and the enlarged Union, point towards the same kind of reforms. That is, to further scale-down support given through market prices and to redirect support for more socially legitimate objectives, such as environmental and cultural landscape enhancement and rural development. It is argued that market stabilisation remains a legitimate object of public intervention, and that to move the policy in the desired direction from the present position, a further category of transitional adjustment assistance will have to be paid. Finally, mention is made of some of the factors which will determine the impact of the policy changes discussed on crop protection.

INTRODUCTION

The European Commission presented an agricultural strategy paper to the Madrid Council meeting in December 1995 which concluded that the status quo was not a viable option. It argued that the 1992 reform process should continue and Europe should move towards a more integrated rural policy. This paper will review the arguments leading to this conclusion and will explore the main elements of such a policy. Given EU decision-making procedures, such reform will take several years to accommodate. To sustain the momentum for such continued evolution of the CAP, it is important to have a clear analysis of why it has to change and the kinds of changes necessary. This will be addressed here in three

[1] The opinions and judgements contained in this paper are those of the author alone.

stages. First, and briefly, to underline why for current domestic reasons the 1992 reforms have to continue. Second, more fully, why the policy has to change to suit the needs for the future Europe, with up to 27 member states including 490 million citizens and perhaps in excess of 15 million farmers. Third, imbalanced support (the outlines of what might be called a more integrated rural policy) will be sketched. There is no point in trying to flesh out the details of that policy until there is consensus about what is wrong with the present arrangements and common objectives for a reformed policy. Because these changes in the CAP are both speculative and several years away, the implications for crop protection are addressed only in a rather general and qualitative way.

WHY THE 1996 CAP STILL DOES NOT FIT THE EU-15

Europe's agricultural and rural policy is, of course, primarily a matter for Europeans. The primary reasons further adaptation to the CAP is under discussion is that there is a widespread view within the Union that the present CAP is not ideally adapted for the EU-15. Also, it is equally clear that it will not suit the kind of wider and deeper Europe in the course of construction. Purely from the point of view of the interests of Europe's own consumers, taxpayers, farmers, its rural environment and internal economic interests, it has been clear for many years that the 'old-CAP', which tried to achieve nearly all its objectives through the Common Market Organisations (CMOs), was no longer appropriate. Surpluses of numerous products were accumulating which were saleable only with large export subsidies. In the process, farmers were encouraged to ignore market signals and to focus on quantity not quality. Farmers, therefore, overlooked their vital role as creators and stewards of the kind of rural environment society treasured. The policy, which was founded on the need to stimulate an undercapitalised, peasant agriculture at a time of food insecurity, had served its purpose and was ripe for change. The first real sign that these lessons had been learned was in 1992, when the most significant step in the evolution of the CAP occurred[2].

The changes made to the CAP during the 1990s, in combination with the developments in international markets and policy changes elsewhere, e.g. the Uruguay Round Agreement on Agriculture (URAA), and changes in Central and Eastern Europe plus the run-up to the 1996 US FAIR[3] act, have certainly had their effects. European agricultural markets are in better balance than for many years, stocks of all products have fallen, the run-away growth in FEOGA[4] expenditure has been controlled, farmers' incomes have stopped falling and, in many member states, have risen. Thus, relatively speaking, "all's quiet on the agricultural

[2] Some will argue that the CAP was repeatedly adapted and changed throughout its life, and that's true, it has been a remarkably resilient policy withstanding huge internal and external shocks. However it was not until the 1992 reform that there was a significant recognition, at least for cereals, that the fundamental problem was that for one of world's largest net-exporters to be basing its policy on higher than average world prices is suicidal.

[3] This refers to the 1996 Farm Bill, the Federal Agriculture Improvement Reform - FAIR - Act.

[4] FEOGA is the Fonds Europeen d'Orientation et Guidance Agricole, commonly known as the CAP budget.

front"[5]. This should be an ideal atmosphere in which to review the workings of EU agricultural policy. It is a real test of the maturity of European political institutions to show that its most developed sectoral policy can be adapted without the necessity of a crisis induced by overwhelming budgetary or external political pressure.

So, from an internal perspective, what is wrong with the present CAP? This will be discussed under three headings: imbalanced support, supply management and compensation payments.

Imbalanced support

Since 1992, institutional prices for wheat, barley and oilseeds have been significantly reduced so they are now at, or even below, world market prices. However, there are still very high prices for dairy produce, beef, sugar and rice. This makes little sense. Apart from the costs imposed on consumers and taxpayers to maintain these high price regimes, because of the capacity for chronic overproduction at the supported prices, it is necessary to have a battery of strict supply management and other restraints to control the markets. This imposes constraints on farmers, it represents a rejection of the benefits of the European single-market principle and it prevents European farmers claiming a share of the growth in world markets for grains, dairy produce, meat and processed food products. But the inconsistencies in the CAP go much further than these prices imbalances. Measured in terms of FEOGA budgetary spending, nearly all EU public policy interventions are still focused on market price support, when practically all the former justification for doing this has evaporated[6]. What are the market failures which the EU's highly developed system of commodity-specific, intervention, border protection and compensation payments try to correct? Most people would claim that the most important problems are those concerned with the protection of food quality, soil, water, atmosphere, biodiversity, habitats and landscape, and also with the development of balanced and viable rural areas. However, pursuit of the CMOs often works in opposition to legitimate goals in these areas. The down-scaling of cereal, oilseed and beef prices in the 1992 reform (together with the agri-environmental 'accompanying measure'[7]) was a very significant step in trying to correct this imbalance, but much remains to be done.

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[5] Outside the disaster of the beef market, which has nothing to do with the CAP.

[6] There is no space to develop the theme here; it was well examined by the UK Minister of Agriculture's CAP review group 1995, which concluded that the prime objectives of the CAP to stimulate productivity improvement and secure food supplies have been achieved. It accepted that an important remaining area of market failure is in the notorious instability of agricultural product markets and the inability of an atomistic industry to deal with this unaided. However, the stabilization objective does not justify the scale of intervention in the CAP for the last two decades.

[7] The very name 'accompanying measure' indicates that the other elements of the policy change, the set-aside and compensation payments were the real horses in the 1992 race. The three accompanying measures were the also-rans.

Supply management

Despite much opposition from farmers (for example, to milk quotas at the time of their introduction), in a short space of time most became strong supporters of supply management. Schemes are now in place for sugar, milk, cereals, oilseeds, protein crops, beef and sheep. The initial opposition is always because there is a reluctance to accept the loss of some 'freedom to farm'. This is soon replaced by appreciation of the benefits to the present generation of farmers as they capture rents from consumers, from future farmers and from all of us in the form of inefficient resource use. This is achieved, of course, by increasing the scarcity of the product and by jacking-up prices. Furthermore, having institutionalised support in this way, farmers know that they can try and extract compensation from society if these quota rents are threatened in the future. The criticisms of supply management are, thus, the resource costs, the inflation of land values (with its consequences for new entrants to farming) and its stifling of innovation and development. It is no accident that it is criticised most strongly by those farmers who are the most productive. They can see opportunities to expand their businesses and to find additional markets domestically and outside the Union, but are prevented from doing so by the collectively agreed constraints. The 1996 grain market situation adds a strong moral argument for Europe. What is the justification that, at the time when grain prices are at their highest ever recorded, the richest economic bloc in the world (the European Union) requires its farmers to 'set-aside' ten per cent of some of the world's most fertile and stable farming land? The price paid for this policy falls on importing regions in the world, who happen also to be the poorest[8].

Compensation payments

Compensation payments were a vital element in the 1992 reform. They constituted the political oil to ease the friction caused by the desire to significantly reduce the institutional prices of cereals, oilseeds and beef. The regulations which introduced them, referred to them as 'compensation', that is, a correction for injury suffered by a change in policy[9]. For decades, farmers had been encouraged to invest and produce, by a policy of strict border controls and by intervention buying to keep up domestic prices. When it was decided (in the light of the new circumstances of Europe and its place in the world) to change strategy, it was considered reasonable that people were compensated for the change. However, it is plain that there are at least two severe problems with these payments. First, in practice, the payments have not been related to the injury caused. It was predictable that the combination of the Uruguay Round-induced reductions in protection, the change from

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[8] It might be objected that liberal economists complained on behalf of less-developed countries when the EU took actions which depressed world prices and thus reduced incentives for LDC farmers, now they complain when the EU takes action which raises world prices! A partial response is that it is the destabilisation effect which is the important point. The EU is such a significant actor on world agricultural markets now that it should take on more responsibility not to destabilise international markets for its own domestic purposes.

[9] In this regard, it is illogical to complain about the distribution of the payments and, in particular, the large payments to large farmers. If society agrees to pay compensation then of course the most injured get the biggest payment.

variable levies to tariffs and the CAP reform, would both raise world market prices and loosen the relationship between EU institutional prices and market prices. Also, the collapse of the Exchange Rate Mechanism of the European Monetary System meant that institutional prices in devaluing countries rose rather than fell. As an order of magnitude, it can be calculated that the over-compensation of cereal farmers is about 11 billion ECU in total for the period 1992/93 to 1995/96.[10] Second, compensation for a once-off policy change cannot continue indefinitely. These two problems suggest defining more clearly the justification of continued large transfers to agriculture and rural areas. In today's circumstances, there are four possible justifications for significant interventions and resource transfers: (1) stabilisation of agricultural markets; (2) the purchase of public environmental goods and services; (3) the encouragement of rural development; and (4) what could be called adjustment assistance. However, for each of these there has to be a process of redefining the objectives of the policies and the mechanisms through which they are achieved. This is outlined briefly in the final section of this paper.

WHY THE 1996 CAP WILL NOT FIT AN EU-27 IN THE 21st CENTURY[11]

The direction for CAP reform, indicated with reference to EU domestic interests, turns out to be the same as that indicated by the wider considerations of some more general pressures in the Union. These arise from the move towards a more liberal trade regime both for intra-Union trade and international trade. This is manifest as the 1992 completion of the internal market and the EU support for the achievements of the 1994 Uruguay Round Agreement, which, for the first time, included a comprehensive set of commitments for liberalising agricultural trade.[12] The trend towards a more liberal trade regime is expected to continue with the next round of multilateral trade talks under the World Trade Organisation (WTO) in 1999, and it is further propelled by the development of free trade areas which, post URAA, will have fully to embrace agriculture. It is wrong to depict these (as they so often are) as 'external' pressures. This would imply that the EU was forced to adopt them by other trading partners, which is not the case. As the largest economic and trading bloc in the world, the EU had a strong *internal* imperative that the fullest benefits of freer trade are achieved for its citizens. Its agriculture had stood for so long outside this movement, but is now irrevocably and beneficially part of this worldwide trend.

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[10] This was calculated by comparing the 1992/93 EU average producer price for each of the cereals with the sum of the corresponding price in each successive year and the compensation payment expressed per tonne. This provides an estimate of the unit over-compensation because the compensation was intended to 'make-up' the reduction in prices since 1992/93. The unit over-compensation is then grossed up by the volume of production of each grain.

[11] This refers to the enlargement to include Malta and Cyprus plus the ten Central and Eastern European Countries (CEECs) which have association agreements with the Union, from North to South: Estonia, Latvia, Lithuania, Poland, Czech republic, Slovakia, Slovenia, Hungary, Romania and Bulgaria. Of course there is no guarantee they will all accede at the same time or at all, and there are also other countries now shaping up to discuss association with the EU in the former Yugoslavia. Thus reference to the EU-27 is intended to be illustrative of a 'much bigger' Union.

[12] See Tangermann (1996) for an excellent, detailed assessment of the achievements of the agreement.

These trends to more liberal trade mean that it will become progressively more difficult for the EU to maintain its domestic prices significantly above world market levels, necessitating high border protection and export subsidies. There seems to be a consensus amongst the markets managers in the Commission and member states that these pressures can be lived with until the end of the URAA but will become more and more difficult thereafter.[13] If, as expected, the WTO further reduces export subsidy volumes and values and tariffs these pressures could become unbearable.

The other broader and longer-range issue driving the EU to consider its optimal policy is the prospect of further enlargement. There are several cogent reasons why it would be most unwise to try and squeeze the CEECs into the present CAP. They are mostly intensified versions of the same arguments of why the 1996 CAP is not ideal for the EU-15 either. This is another issue which is often, and wrongly, depicted as an 'external' pressure on the EU. This is not the appropriate place to analyse the route by which Europe arrived at the momentous events of autumn 1989. However, since that year, the countries of Central and Eastern Europe decided, for the most part, peacefully, to change their political and economic systems, and to seek close integration with the institutions of Western Europe. These feelings were reciprocated in the West. The EU's political, security and economic interests were seen to be served by creating the fastest and closest ties with these transition economies. This has been pursued by the Association agreements and the commitments that the CEEC-10 may become full EU members.

It was quickly realised that these developments were highly significant for the development of agriculture in Europe. The sheer scale of the prospective Eastern Enlargement (ten countries with 110 million people, and their relatively greater dependence on agriculture) stimulated concern in the EU. Initially, during 1992 and 1993 the concern was mostly about the social consequences of the alarming disintegration of agriculture as prices were liberalised and the sector began restructuring[14]. However, as signs of recovery were detected, the concern switched to the consequences for the EU and especially for the CAP of the Eastern enlargement.[15] The Commission itself studied these issues closely. In July 1995 it published individual studies and a summary report for the ten CEECs (European Commission, 1995a), in which the policy and agricultural developments post-reform were summarised and an attempt was made to get a feel for the magnitude of the potential net agricultural trade position of these countries by the end of the century. This was followed, in December 1995, by the publication of the 'Agricultural Strategy' paper under the names of both the Agriculture and Rural Development Commissioner (Fischler) and the

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[13] The difficult products are some dairy products like powdered milk, some processed foods, and, since the crisis with Bovine Spongiform Encephalophy (BSE), beef.

[14] This shows up clearly in the report prepared for DGVI of the European Commission by Nallet & Van Stolk (1994).

[15] This change in emphasis is clearly seen in the four 1995 studies requested by DGI of the European Commission by Buckwell *et al.* (1995), Mahé *et al.* (1995), Tangermann & Josling (1995) and Tarditi *et al.* (1995).

Commissioner for External Relations (Van den Broek) (European Commission, 1995b), which was received by the Madrid European Council and the Agricultural Council.

The strategy paper set out the challenge posed by the enlargement. It reviewed the likely development of the CAP particularly as the Uruguay Round Agreement on Agriculture was implemented over the period 1995–2001. It considered in some detail the effects on the major commodity markets of the adoption of the 1995 CAP by the CEEC-10 over the period 2000–2010. It examined three options for dealing with this enlargement: (1) to keep the status quo, to squeeze the CEEC-10 into the existing CAP, adjusting the current set of instruments, prices, quotas and set-aside to deal with any problems which arise; (2) radical reform, to dismantle the support arrangements under the CAP; and an intermediate option (3) to continue the 1992 reform process, move to a more integrated rural policy and at the same time achieve a simplification of agricultural policy. The Commission concluded that option 3 was clearly the preferred strategy.

The initial political reaction to this document have been quietly favourable. No significant group has suggested that options 1 or 2 would be preferable or that there is a fourth possibility, significantly different from the direction indicated in option 3. There are five issues concerning the application of the present CAP to the CEECs: the budget costs (along with the triad of problems of applying: high prices, supply controls and compensation payments in the CEECs); and the difficulties of living with the amalgamated Uruguay Round commitments.

WHY THE 1996 CAP WILL NOT FIT AN EU-27 IN THE 21st CENTURY

Contrary to popular wisdom, the principal problem for agriculture of extending the present CAP to the CEEC-10 is *not* the budgetary cost. The Commission's calculation of the order of magnitude of this cost put it at 12 BECU, considerably less than the figures estimated by most other commentators[16]. The interpretation of this sum is that it is, of course, a considerable amount to be raised from EU taxpayers, and it will not be easy. Also, it is recognised that the figure quoted is only part of the cost of enlargement; it does not include the costs of applying the structural and cohesion measures or other European Policies. However, it is within the estimated financial guidelines for agriculture, and it is judged to be politically manageable. It is well recognised that there is bound to be a significant budgetary expenditure associated with enlarging the EU to so many countries which are both poorer and more agricultural that the existing EU-15. Furthermore, it is recognised that there are considerable economic opportunities offered by the integration into the Union of what is hoped and expected to be an economically dynamic part of Europe.

The problem of high prices

The real problems of extending the 1996 CAP to the CEECs concern the internal economic

[16] See Buckwell *et al.* (1995) for a review and explanation of the wide range of the estimates of budgetary cost of CAP in the CEECs.

effects of the CAP on those countries and the feasibility and wisdom of applying the present panoply of prices supports, border protection, supply management and compensation payments. Even after the 1992 reforms, the EU maintains farm-gate food prices which are significantly above those found in the CEECs. The Commission estimated the gap in 1994 to be of the order of 20%–40%, varying by commodity and country. This is not a static situation; protection in the CEECs has risen since the early years of liberalisation, and may rise further, partly closing this price gap. However, this process is limited by the desire not to raise food costs for the population[17]. The average expenditure share on food in these countries is over thirty per cent (nearly twice that in the EU-15). There is considerable variation around this figure, with much higher shares for pensioners and others on low and public-sector incomes. Policies which raise food prices can cause considerable social stress and, also, will have a detectable effect on wage costs to the detriment of the competitiveness of these economies. The burden of EU food price levels on CEECs would thus dampen their ability to grow rapidly, inflicting a heavy cost on them and reducing the benefits of enlargement to the Union.

The problem of supply controls

The second problem of applying the 1996 CAP to the CEECs is that it would involve implementing the detailed farm-level, supply control measures which are an integral part of the cereals, oilseeds, milk, sugar, beef and sheep regimes. Whilst the CEECs previously had a very rigid system of farm level plans and controls on production, this whole system has been abandoned in the last five years. It would be ironic indeed if the EU encouraged them to restore such detailed production controls. The present patterns of farm structures and formal and informal land leasing arrangements in the CEECs (which are quite different from country to country) could make it difficult to implement and enforce arable set-aside and also, especially, milk quotas. For the former, whilst much of the grains land is still *farmed* by quite large co-operatives, a lot of this land is owned, usually in small and fragmented parcels, by absentee landowners. There would be an enormous temptation and opportunity to arrange the application of the set-aside so that much of the land is entered by the owners into the simplified scheme, thus avoiding the need to put land out of production. If this came about it would create further tensions in the operation of the scheme in the Union. The application of milk production quotas also poses practical difficulties. Milk production in the CEECs was, pre-reform, extremely concentrated on a few, very large holdings. It has contracted drastically by, on average, about 25% and is now much more fragmented. Both these features will make it very difficult to apply quotas. Also, the CEECs would be very reluctant to curb their milk production for all time based on the low levels of output achieved after the dislocations of the transition process. In these circumstances the policing of quotas on a highly fragmented dairy system would pose great practical problems – the incentive to avoid their effects would be immense. Thus, the CAP supply control measures, which are an explicit part of the price-raising apparatus, pose problems of both principle and operation. No doubt, with the ingenuity demonstrated down the years as the CAP has evolved, the practical difficulties of implementing supply management could be

[17] The rise in protectionism in CEECs is also limited by the budgetary resources available to agriculture in these countries and their own URAA commitments.

overcome. However, the principle that they would damage the interests of CEEC consumers *and* producers suggests that it would be preferable to avoid this.

The compensation payments under the CAP

These create a very difficult dilemma. The Commission Strategy document recognised that there could be no justification for making the 'compensation' payments to CEECs if they did not suffer the institutional price cuts which justified the payments. But equally, it was recognised that it is inconceivable that in a *common* agricultural policy half of the farmers (generally the richer ones) are in receipt of significant direct payments and the other half (the poorer ones, from the CEECs) are not. The option of ignoring the origins of the compensation payments and simply extending them to CEEC arable and livestock farmers is considered most unwise. Given the size of the payments in relation to current levels of gross margins in CEECs they would be extremely distortive. They would underwrite land values at levels much higher than justified by local conditions, creating more problems for the necessary rationalisation of farm land ownership. They would also be very difficult to administer in the CEECs, where the production co-operative is emerging as the most common production structure. To whom would the money be paid? How would it be distributed amongst the various claimants – the land owners, the co-op members supplying labour and those supplying capital, and the non-member employees (who, in some CEECs, are relatively disadvantaged non-land owning groups)? To the extent that the payments accrue to land owners, part will escape from the rural areas because the land restitution process has returned land to families who long-ago left the land for the cities. Resolving this distribution problem would be a problem for the CEECs, but it could involve some difficult social tensions. Furthermore, how could it be justified in the villages of the CEECs, that those engaged in farming are recipients of ECU-denominated, extremely generous payments from the EU budget whilst unemployed rural industry workers receive nothing? It would be socially divisive and potentially destabilising. Of course, as argued above, some of these same difficulties exist within the EU-15. The conclusion is clearly that the basis of making long-term direct payments to farmers has to change so that, ultimately, a single support system can apply to the whole, enlarged, Union.

The word 'ultimately' was included in the last sentence because the idea of buying time to change the compensation payments was clearly signalled in the Commission Strategy document. It was argued that for a transition period, after accession, instead of receiving compensation payments, the CEEC agricultural and food industries would be better served by a special programme of structural and modernisation assistance, to enable them to survive and thrive in the fierce competition of the single market. Without being explicit, the implication was that the period from now to the end of such a transition period provides the time for the EU-15 to amend the compensation payment system and get into place alternative arrangements which can be applied universally across the enlarged Union.

Respecting the Uruguay Round Agreement on Agriculture

This also poses a significant problem for applying the 1996 CAP to the CEECs. Not all the CEECs are yet members of WTO, but it is presumed they will be by the time of EU accession.[18] All CEECs will, therefore, bring to the EU their own schedules of import tariffs, minimum access volumes, subsidised export values and volumes and their aggregate measure of support (AMS). One part of the accession arrangements will be the harmonisation and aggregation of these schedules with those of the EU. This could cause difficulties with all of the commitments. The problems of harmonising up or down the tariffs will, no doubt, be complex and protracted. It may even involve agreeing compensation for third countries who are injured by loss of access to CEEC markets. However, experience with this has been gained from the EFTA enlargement. Such matters are the very stuff of international trade relations and can presumably be settled by the normal process of negotiations. It is the volumes and values of subsidised exports where it is expected that most problems could arise. If, as expected, at the time of enlargement, EU prices are in their usual position of being above world market prices and, furthermore, if CEEC prices upon accession are below EU prices, then two consequences arise from the accession when CEEC farmers and consumers face the higher EU price levels. First, the effect on the markets is to increase the net export surpluses. Second, given the assumed price relationships, to dispose of these surpluses will require export subsidies.[19] The magnitude of this problem is hard to assess. It requires difficult judgements about, EU, CEEC and world prices; it also requires assumptions about the rate of technical progress and supply responsiveness of CEEC farmers and about the rate of economic and consumption growth in the CEECs. The Commission (and others) have made such assumptions and calculations, and the results all point to the accumulation of export surpluses far in excess of the likely aggregate 'volume' commitments of the EU-25. Furthermore, these relate to the current Uruguay Round commitments; by the middle of the next decade it is likely that these will have been further reduced by the first WTO 'round'. The problems of over-production could, of course, be resolved by increasing set-aside or by reducing production quotas, but it has been argued above that such an approach is not practicable or sensible for the CEECs (or the EU-15).

In short, from the perspective of the economic interests of the CEECs, the present CAP is unsuitable with its relatively high prices, its cumbersome and distortive supply management which would peg CEEC production at historically low levels, and inappropriate compensation payments. Furthermore, even if these judgements were ignored and the CEECs adopt the CAP in more-or-less its present form, there is clear potential for increasing the net surpluses at the current price and support levels; this in turn will create severe problems of surplus disposal in a world committed to eliminating export subsidies. These arguments point to the necessity of further reform of the CAP in the direction already started: that is, to move to a more market-oriented agricultural system which will simultaneously reduce the consumer burden and eliminate the need for export subsidies and supply management. At the same time, there is a big challenge in the CEECs to pursue their

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[18] As of September 1996 since Bulgaria joined the WTO in July, all the CEEC entrants except the three Baltic States were WTO members.

[19] Note that the problem of exceeding URAA export volume constraints is not a new feature created by the enlargement. There are clear grounds to expect that without any significant change in either policy or market conditions, the EU-15 will have difficulties in living within their own commitments by the early years of the next decade.

agricultural restructuring and to create competition in their food processing and distribution sectors. This would spur the improvement of quality standards and efficiency in those sectors. It is also clear that CEEC agriculture has a great deal more adjustment to make in improving labour productivity. This will inevitably involve a further, and perhaps quite large, outflow of labour from the primary sector. Given the historic legacy of poor labour mobility in those societies, much of this labour will remain in rural areas and, given the pressure on urban employment and public services, it is probably better if it does stay there. This, in turn, points to the necessity for comprehensive rural development actions to stimulate the creation of appropriate economic activity in these areas. Thus, there is no contradiction between the needs of both CEECs and the EU-15 for a new emphasis in agricultural and rural policy.

WHAT KIND OF CAP IS SUGGESTED?

The legitimacy of the CAP is in grave danger. Whilst, over the years consumers and taxpayers have tolerated the drain on their resources, this was because of the feeling that farmers were a deserving group in society who worked hard, they ensured the security of our food supplies, produced in all weathers and looked after the countryside. However, gradually, memories of food shortages have been replaced by anxiety about food safety and quality, shortage has turned to surplus, farmers themselves have turned from peasants to entrepreneurs and in the process have intensified farming in ways which have damaged the rural environment. When agricultural productivity and food market stability and security were seen to be the major problems, it made some sense to base agricultural policy around the common organisation of markets. These agricultural problems have largely been solved. The European Union has grown to be the World's largest industrial and services supplier with a free internal market. It has also developed into the world's largest player in international food markets. In such circumstances, its agricultural strategy had to change as it started to in the early 1990s – moving away from market price support, and moving to a system of support which better balances and integrates the desire for farmers to play their full role as competitive providers of wholesome food and also providers of public environmental goods and contributors to balanced rural development.

It is vital that the potential new member states understand these new directions for the CAP. It would be enormously disruptive for them to create expectations amongst their farmers that they will join a Union with the open-ended support policies of the 1980s. It has been argued that none of the three main elements of even the post-Mac Sharry CAP suits the CEECs. The high support prices for many commodities, the supply controls and the compensation payments should all be substantially modified if not removed altogether, if not before they join then certainly before their transition is complete[20].

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[20] Whilst it has been argued that supply controls are against the interests of consumers and producers in the CEECs, it is predictable that their farmers will go through the same metamorphosis as EU farmers: initial opposition changing into strong support. This is a further warning that if it is not possible to tackle milk and sugar quotas and other supply restriction schemes before Eastern enlargement, it will prove to be even more difficult to achieve post-enlargement.

At the same time as Europe is developing the confidence to see its role as a competitive agricultural exporter, it is also taking the lead in showing how agriculture can play the dual role as a provider of both food and rural environmental and cultural services. These different outputs of European agriculture are, and always have been, inextricably intertwined, much more so than in the Americas and Oceania. Agricultural activity occupies a much larger fraction of the total land area in Europe than, for example, in the USA, Canada or Australia. European society is well aware of its rural roots, and values the natural environment and cultural heritage of rural areas. Until the pressures of agricultural development threatened the delivery of the environmental and cultural services they were taken for granted. No special actions were considered necessary for their provision. Now it has been realised that not only must there be specific public actions to protect natural resources and enhance the environment, but that these actions must be integrated with other dimensions of agricultural and rural policy. It is increasingly seen that even in the most agricultural of rural areas, farming provides only less that a quarter of employment and economic output. It is the territorial dimension which agriculture dominates. Thus, viable rural areas require a judicious blend of a healthy and sensitive agriculture plus a mix of other activities. This means that agricultural policy should shift from being essentially a sectorally defined commodity support system, and broaden to become a territorially defined set of support measures to provide for a stable and efficient food-producing sector embedded in a sustainable rural environment.

A number of new ideas, for what this more integrated policy could be, are now emerging. It is suggested that it should contain the following features. There should be a continuation of the reduction in supports through CMOs, so that all that remains of this set of commodity specific measures are instruments of Market Stabilisation (MS). At the same time as support is reduced through the CMOs, there should be a build-up of Environmental and Cultural Landscape Payments (ECLPs) and Rural Development Incentives (RDI). The balance of support, to ensure acceptance of the transition from the current arrangements, should be based around the concept of Transitional Adjustment Assistance (TAA).

The most critical aspect of 'reducing support through CMOs' is whether domestic prices can be reduced to average international levels. If they can, this eliminates two critical features of the present CAP. First, there is no fear about meeting the export subsidy constraints – because if domestic prices are equated to international prices then no subsidies are required. Second, there is no need for systematic supply controls, because, by definition, whatever domestic producers choose to supply can be sold at the international price. However, it is recognised that the atomistic structure of agriculture (coupled with its exposure to weather, disease and exchange rate instability) justifies some publicly organised Market Stabilisation measures for agriculture. Of course, it could be debated whether it should be prices, quantities or incomes which are stabilised, but given the history of the last 30 years, it seems inconceivable that the EU could turn its back on *all* market intervention. The fear of heightened instability of international markets since the 'deregulation' of the Uruguay Round makes this even less likely. However, there are various forms such stabilisation could take. It could be based on one or a combination of the following: crop or revenue insurance; safety-net intervention; strategic stock holding and management; safeguard border measures; possibly even, for some commodities, supply controls; plus, actions to stimulate farmers and traders to find private solutions to the problems caused by price instability. However, the acid test is that periodic stabilisation does not turn into systematic support as evidenced by stocks accumulating, the chronic need for subsidised exports or massive border taxes.

The Environmental and Cultural Landscape Payments (ECLP) represent a consolidation and expansion, perhaps even a very significant expansion, of existing measures[21] to protect and enhance the rural environment and cultural heritage. Whilst all farmers must respect basic standards of resource protection without payment (i.e. farmers cannot be the only group in society exempt from the 'polluter pays' principle), it is recognised that a great deal of what we treasure in the countryside is produced through, and in conjunction with, farming activities; thus, if we want these features we must pay for them. To ensure social acceptance, such schemes and payments must be explicitly and strictly target-driven. Farmers will contract to supply certain environmental or cultural landscape services and will be paid for them. However, payment must be on condition of delivery; thus, there must be strong monitoring and evaluation built into such programmes.

The principal aim of Rural Development Incentives (RDI) is to stimulate economic activity in rural areas. This will bring together many aspects of present Objective 1, 5a and 5b programmes but extend them beyond agriculture itself, to encourage and create more diversified and balanced rural economies. Actions under these schemes will help improve productivity and quality in agriculture and non-agriculture, as well as supporting infrastructural developments, human capital development and, even, institutional development in rural areas. These actions are important enough in the EU-15, but will be even more important in the CEECs.

Starting from the present balance of expenditures and actions under the CAP, building up legitimate, targeted programmes for Rural Development Assistance and Environmental and Cultural Landscape Payments will take time. In the meantime, therefore, there has to be some kind of cushion to ensure that the policy change does not dislocate agriculture, rural society or the environment. It is the purpose of Transitional Adjustment Assistance (TAA) to provide this cushion. It clearly grows out of the existing compensation payments, and should extend over more of agriculture, e.g. all the grassland as well as the arable area, as the market supports for other commodities are phased down. However, it should have several important differences compared with the present compensation payments. First, it should be forward looking, to help farmers adjust their businesses and lives to the new future rather than being recompensed for past injury. Second, it should not be indefinite, but should taper-off, both individually and in aggregate, after a suitable adjustment period. Third, it should take *some* account of the general and specific economic circumstances. Thus, it cannot be a fixed rate for all farmers irrespective of the state of the market or farmers' individual situation, nor can it last for ever. Fourth, it is reasonable that recipients should be required to respect some environmental conditions for receiving this assistance[22].

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[21] These are found in some of the CMOs and structural measures as well as under Regulation 2078/92, the agri-environmental accompanying measure.

[22] It is very important to distinguish between primary and secondary objectives of these instruments. The concept of 'eco-conditionality' or 'cross-compliance' implies that ecological conditions are attached as a secondary object to a policy instrument which has some other primary purpose, e.g. supply control

If the CAP could be moved in the way outlined, it would facilitate several other important changes in organisation and administration, making a real contribution to simplification of the policy[23]. The RDI, ECLP and TAA schemes must be defined and organised at regional levels but, to prevent distortions to competition, firmly within an EU framework and with EU vetting and approval. This will require considerable regional involvement and constitutes an important part of the legitimation of the policy. Farmers, other land managers, and others contributing to rural development will make multi-annual contracts for various services under the programmes and receive the agreed rates of payments. Many of these, in turn, could be consolidated into a single per-hectare or per-farmer payment. Finally, this new policy may require new definitions and gradations of regions so that the richest and most developed rural areas have a high degree of co-financing and the poorest areas will be able to manage only a much smaller locally financed element. Without such arrangements there would be very real danger of market distortions.

SOME IMPLICATIONS FOR CROP PROTECTION

The author has not studied these questions and is no expert on the Crop Protection Chemical (CPC) market. In addition, the changes discussed here are speculative; they will be the outcome of a political process, so they are subject to great uncertainty. Even if the CAP were to change exactly as outlined, the changes will be introduced over a period of years and are unlikely to start before 1998.

The policy changes described will affect the EU-15 market, and that in new member states in Central and Eastern Europe; of course, such changes will not occur in Europe in isolation, but will be part of a continued global liberalisation of agricultural markets. In the EU-15, the effects of the combination of reduced support and protection of the major supported crops, and a more open trade regime, will be complex and will differ from crop to crop. What might be the effect of simultaneously (over a period) reducing the intervention price, reducing the import protection, eliminating the export subsidies and also eliminating the set-aside requirement? The impact on area of cereals could either be positive or negative. Set-aside land would come back into production, but would it all? This, of course, depends on the level of world grain prices. However, this in turn depends on other developments in world markets, especially economic growth rates in Asia, as well as policy changes in other regions, for example, in the former Soviet Union. The same uncertainty surrounds the likely intensity of production and, hence, grain yields and the use of CPCs.

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or revenue compensation. The danger of this approach is that the environmental achievement is then subordinate to the primary objective. Thus, if the need for set-aside or compensation drops one year the environmental gain drops with it. This is the reason that there must be an explicit environmental programme to achieve the environmental services society wishes to buy.

[23] There is little doubt that the CAP should be simplified, and that finding a way to consolidate support payments into a single direct payment to farmers in return for a multi-year contract could be a simplification. However, it has to be acknowledged that, in principle, the switch from market support to direct farmer payments for services rendered could be administratively complex (especially as there is a strong desire to use the territorialisation of the policy to allow more local diversity).

These are price sensitive, and it is very hard to foresee the outcome without specifying a detailed set of assumptions about all the mentioned factors and doing a thorough modelling exercise. It is not possible *a priori* to argue convincingly whether the removal of current grain market support in the context of the WTO round and Eastern enlargement of the EU would increase or reduce grain output in the EU-15. For the currently more heavily protected 'crops' like sugar, tobacco and wine where there are no set-aside provisions, the effect of removing support is clearer. Area and production of these crops is likely to decline, with consequent effect on CPC usage. Of course, it could be expected that the contraction in each case should be from the (economically) marginal producers. The author has no knowledge of whether these producers are heavier or lighter users of CPCs. The main effect of the changes in policy in the livestock sector impinging on the crop protection sector will presumably be through the effects on milk production. Here again the effects are difficult to predict without a carefully specified set of assumptions. In particular, it is not clear if total milk production would rise or fall in a liberalised market.

The changes in crop areas and yields in response to changes in the market support arrangements are not the whole story. The more integrated rural policy substitutes environmental support and rural development incentives for the market support. The first of these is likely to be associated – if anything – with reduced use of CPCs. This is not axiomatic. It is most likely that the major beneficiaries of the environmental payments schemes will be the high-nature-value farming systems outside the major arable areas. However, if the policy moves as suggested and if it becomes a territorial policy which is implemented regionally, then there is likely to be a great deal of variation in the way it is implemented.

In short, in the EU-15, to the extent that current CPC usage is associated with production of crops whose exports are subsidised or with production which is unsustainable and polluting, then it will/should fall under the policy changes described. However, there are some arguments which could point to expansion of EU crop output and thus CPC use. To the extent that there is growth in world markets, a less protected EU which can, therefore, escape from the chains of supply controls, could contribute to greater exports of cereals (wheat & barley), possibly of some fruit and vegetables and, even, dairy products.

Turning to the CPC market in the CEECs, the effect on them of the new Rural Policy outlined is even harder to predict. Economic conditions, the extent and outcome of the farm restructuring in these countries and, thus, the capacity to respond to new circumstances vary enormously between the CEECs. In general, there is considerable capacity to upgrade their technology of production. In particular, most of them have a lot of catching up to attain EU standards for clean crops and disease-free produce. The impact on them of joining a reformed CAP (which involves, essentially, international prices) raises many of the same uncertainties as listed above for the EU. With the exceptions of Romania and Bulgaria, most of the CEECs are currently indulging in protection of their own farm sectors. In fact, several of them (especially Slovenia but, also, to some extent Poland, Hungary and the Czech Republic) are trying to ape the current CAP and are employing, or proposing to employ, some of the CAP support instruments: intervention, export subsidies, quotas and set-aside. If they continue in this vein and then discover that the EU is liberalising, they might find the same adjustments in store for them, as already described for the EU. Only in Bulgaria and Romania would accession to the CAP stimulate a large positive production reaction – but these two countries are probably low in the order of potential new entrants. Overall, the impact of the changes for CEEC markets for crop protection of adoption of the reformed CAP is a balance between the 'modernising' effect of joining the EU and adopting its farming technology, counterbalanced by the possible effect of reduced prices and introduction of more environmentally benign production. To some extent, within the enlarged Union, lower-cost CEEC production may displace EU-15 production. The impact of this switch on crop protection would need careful crop-by-crop and country-by-country analysis.

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SESSION 2A

NEW COMPOUNDS, FORMULATIONS AND USES FOR DISEASE CONTROL

Chairman	Dr K Brent *British Crop Protection Council, Farnham*
Session Organiser	Dr P Gladders *ADAS Boxworth, Cambridge*
Papers	2A-1 to 2A-6

DPX-JE874: A BROAD-SPECTRUM FUNGICIDE WITH A NEW MODE OF ACTION

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ABSTRACT

DPX-JE874 [3-anilino-5-methyl-5-(4-phenoxyphenyl)-1,3-oxazolidine-2,4-dione] is a highly active new fungicide which provides excellent control of a broad spectrum of plant pathogenic fungi at 50-200 g.a.i./ha. Field trials, conducted over several years around the world, show that DPX-JE874 is particularly effective against grape downy mildew; potato and tomato late and early blights; wheat leaf and glume blotch; and barley net blotch. Control of many disease in several other crops has also been observed. Mixtures of DPX-JE874 with selected fungicides enhance its biological activity against these diseases.

DPX-JE874 has outstanding protectant, translaminar, and residual properties. The fungicidal activity of this molecule is attributable to the inhibition of fungal respiration. This novel mode of action allows it to control phenylamide-resistant strains of downy mildews. The product is safe to both users and to the environment.

INTRODUCTION

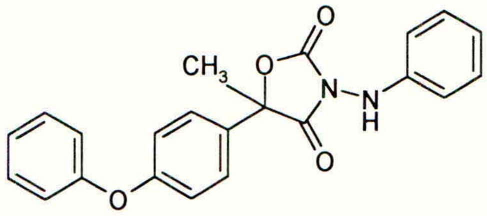
DPX-JE874 is a novel oxazolidinedione fungicide discovered and patented by DuPont. It arose from a successful collaborative chemical design and synthesis program between DuPont and Professor Detlef Geffken of the University of Hamburg.

Although several plant pathogens belonging to ascomycete, basidiomycete, and phycomycete genera are controlled, this paper presents data on the chemical and biological properties of DPX-JE874, with particular emphasis on fungal pathogens of grapes, cereals, potatoes and tomatoes.

CHEMICAL AND PHYSICAL PROPERTIES

Common name:	Famoxadone
Chemical name: (IUPAC):	3-anilino-5-methyl-5-(4-phenoxyphenyl)-1,3-oxazolidine -2,4-dione
Code number:	DPX-JE874

Structural formula:



Molecular formula:	$C_{22}H_{18}N_2\ 0_4$
Molecular weight:	374.4
Melting point:	140.3 - 141.8°C
Water solubility:	52 ppb at 20°C

n-Octanol-water partition coefficient: log P = 4.65 at pH 7

Vapor pressure at 20° C:	6.4×10^{-7} Pascal

TOXICOLOGY

Rat acute oral LD50:	>5000 mg/kg body weight
Rat acute dermal LD50:	>2000 mg/kg body weight
Rabbit skin irritation:	non-irritant
Rabbit eye irritation:	non-irritant
Ames test:	negative
Teratogenicity:	non-teratogenic

BIOLOGICAL ACTIVITY

Materials and methods

Plants for the glasshouse experiments were grown under controlled environmental conditions. Inoculations were made by using aqueous spore suspensions of the plant pathogen, and incubated under conditions favourable for disease development. Visual assessments were made as percentage leaf area affected.

Field trials were laid out in randomized blocks with 3-6 replications. The size of plots varied from 10 to 30 m^2. All trials were sprayed with fungicides using either a small plot tractor-spray equipment or a hand-held precision plot sprayer at an appropriate spray volume. Percentage area of leaves or fruit infected were assessed at regular intervals through the season.

Results

Mode of action

DPX-JE874 is a powerful inhibitor of mitochondrial electron transport that specifically blocks the function of the enzyme ubiquinol: cyochrome c oxidoreductase at complex III. Zoospores of *Phytophthora infestans* exposed to DPX-JE874 and other analogs cease consuming oxygen, lose motility within seconds, and lyse shortly thereafter. Table 1 shows that DPX-JE874 is one of the most potent enzyme inhibitors developed to date for crop protection. Additional modes of action, if any, are under investigation.

Table 1. Inhibition of mitochondrial electron transport (NADH to O_2) by various respiration-inhibiting fungicides.

Fungicide	IC50 (parts per billion)
DPX-JE874	4.5
A-5504 (Zeneca)	170.0
BAS490F (BASF)	75.0
SSF-126 (Shionogi)	3500.0

Biological attributes

DPX-JE874 demonstrated outstanding protectant activity against *Plasmopara viticola* in glasshouse tests. Excellent protectant activity also was observed on treated plants maintained under dry or wet conditions for seven days, indicating long residual and rainfastness (Table 2). When applied to the adaxial leaf surface, DPX-JE874 penetrated across the leaf surface to provide excellent disease control. Similar results have been obtained against potato early and late blight diseases.

DPX-JE874 was equally effective against phenylamide-resistant or sensitive strains.

Table 2. Preventive and residual control of *Plasmopara viticola* in the glasshouse.

	Mean % disease control		
Rate (g a.i./ha)	Preventive	Dry residual (7 days)	Wet residual (7 days)
5	99	73	70
25	100	99	96

Dry residual = Inoculated seven days after treatment
Wet residual = Treated plants exposed to 16 hours of dew period each day before inoculation on the 7th day

Field performance

Grapes

In field trials, conducted over several years in Europe, DPX-JE874 has demonstrated consistent and outstanding control of *Plasmopara viticola* on leaves and berries versus commercial standards. Further improvement in activity was observed with a premixture of DPX-JE874 and cymoxanil, (Table 3). Good activity was also observed against *Phomopsis viticola*.

Table 3. Control of *Plasmopara viticola* in France and Italy (1995).

Treatment	Rate (g a.i./ha)	Mean % disease control 7-day interval		10-12-day interval	
		Leaves (8 DAT 10)	Berries (8 DAT 10)	Leaves (10 DAT 8)	Berries (10 DAT 8)
DPX-JE874	50	90.0	84.4	-	-
DPX-JE874	100	94.7	98.8	-	-
DPX-JE874 + cymoxanil	90 + 120	-	-	99.8	99.6
Dimethomorph + mancozeb	198 + 1320	-	-	99.7	93.5
Mancozeb	2800	95.5	80.5		
Untreated①		(35.7)	(77.6)	(100.0)	(100.0)

① % infected leaves or berries 8 DAT 10 = 8 days after treatment 10, etc.

Potatoes and tomatoes

A prophylactic 7 to 12-day spray schedule of DPX-JE874 alone and in combination with cymoxanil gave excellent control of potato late blight (*Phytophthora infestans*) in France and UK (Table 4). Similar results have been obtained on tomatoes.

Table 4. Control of *Phytophthora infestans* on potatoes.

Treatment	Rate (g a.i./ha)	Mean % disease control 7-day interval	10-12-day interval	
		France (4 DAT 4)	France (8 DAT 5)	U.K. (4 DAT 6)
DPX-JE874	100	79.0	-	-
DPX-JE874	150	80.0	-	-
DPX-JE874 + Cymoxanil	100 + 100	-	92.4	95.9
Mancozeb + Cymoxanil	1360 + 90	-	62.6	98.5
Fluazinam	200	-	50.9	-
Mancozeb	1600	40.4	-	-
Untreated①		(85.0)	(96.3)	(68.8)

① % infected leaflets/plant

DPX-JE874 also provided outstanding control of potato and tomato early blight (*Alternaria solani*) at a 10 to 12-day spray interval compared to commercial standards, which were applied on a 7-day schedule (Table 5).

Table 5. Control of *Alternaria solani* on potatoes and tomatoes.

Treatment	Rate (g a.i./ha)	Mean % leaf area affected Potatoes (Brazil, 1992) (5 DAT 4)	Tomatoes (USA, 1994) 36 DAT 2)
DPX-JE874①	70	-	5.0
	90	16.5	-
Mancozeb②	2400	75.7	21.5
Chlorothalonil②	1800	73.5	-
Untreated		88.2	67.5

① 10 to 12-day application interval ② 7-day spray interval

Cereals

Field trials in France, Germany and U.K. have shown very good efficacy of DPX-JE874 against *Mycosphaerella graminicola* (*Septoria tritici*), *Leptosphaeria nodorum* (*Septoria nodorum*), *Puccinia recondita and Puccinia striiformis* on wheat. On barley, DPX-JE874 was highly effective against *Pyrenophora teres,* while suppressing *Rhynchosporium secalis, Puccinia hordei* and *Erysiphe graminis.* The spectrum and level of disease control were further improved to match or surpass those of the current commercial standards when DPX-JE874 was used in combination with flusilazole (Table 6).

Significant yield improvement was also evident when a combination of DPX-JE874 and flusilazole was applied to both wheat and barley (Table 7).

Table 6. Wheat and barley disease control (expressed as mean % disease control).

Treatment	Rate (g a.i. /ha)	*Septoria spp.* (45 DAT 2)	*P. recondita* (35 DAT 2)	*P. teres* (55 DAT 2)	*R. secalis* (53 DAT 2)
DPX-JE874 + Flusilazole	150 + 160	72.0	96.6	73.8	76.4
Flusilazole + MBC	200 + 100	60.0	-	53.8	74.9
Flusilazole	200	-	86.5	-	-
Untreated		(76.0)①	(354.0)②	(58.7)①	(37.0)①

① % infection on flag leaf (L1); ② Number of pustules on flag leaf

Table 7. Effect on wheat and barley yield①.

Treatment	Rate (g a.i./ha)	Yield (t/ha) Wheat	Barley
DPX-JE874 + Flusilazole	150 + 160	8.2	8.2
Flusilazole + MBC	200 + 100	8.0	7.0
Untreated		6.5	6.7

① Means of 40-44 trials

Activity on other crops

DPX-JE874 also provides excellent control of *Pseudoperonospora cubensis* cucurbits); *Phytophthora capsici* and *Colletotrichum capsici* (peppers); *Alternaria brassicae* (oilseed rape); *Ascochyta pisi* (peas); and *Cercospora beticola* and *Ramularia beticola* (sugarbeets).

Crop Safety

DPX-JE874 has been used on a wide range of grape, potato, tomato, wheat and barley cultivars under diverse climatic conditions. It is safe to these crops at anticipated use rates with recommended formulations.

CONCLUSIONS

DPX-JE874 is a broad-spectrum and highly active new fungicide which equals or surpasses current commercial standards in controlling key diseases of important crops. Its spectrum and activity are further enhanced by using it in combination with an appropriate companion fungicide. DPX-JE874 is safe to the environment and crops at recommended rates of application.

ACKNOWLEDGMENTS

The authors are grateful to all of their DuPont colleagues whose tireless efforts over many years have resulted in the successful development of DPX-JE874. Also, our thanks are due to Professor Detlef Geffken for his contributions to the discovery and chemical optimization of this new class of fungicides.

DE-795 - A NOVEL FUNGICIDE FOR THE CONTROL OF POWDERY MILDEW IN CEREALS

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ABSTRACT

DE-795 is a mobile protectant fungicide from a new chemical class with specific activity against powdery mildew. It has a good toxicological, environmental and eco-toxicological profile. There is no cross-resistance between DE-795 and current mildewicides. It has a different mode of action to other fungicides being developed and commercialised.

In cereals, a suspension concentrate formulation has been developed. When applied at early stem extension up to eight weeks protection against *Erysiphe* attack can be achieved on the top, yield contributing, leaves. DE-795 offers a new solution to powdery mildew control in cereals and, because of its new mode-of-action and lack of cross-resistance to current products, will provide a powerful resistance management tool to prevent powdery mildew developing resistance to new, emerging chemistries.

INTRODUCTION

At present two major chemical classes are available for mildew control; both of these chemical groups are Sterol Biosynthesis Inhibitors and include cyproconazole, epoxiconazole, and tebuconazole (azoles) which inhibit biosynthesis through C14 demethylation inhibition (DMI's) (Berg *et al.,* 1988, Koller, 1992) and fenpropimorph, tridemorph and fenpropidin (morpholines and piperidines) work through the inhibition of delta Δ^{14}-reductase and $\Delta^{8}\rightarrow\Delta^{7}$-isomerase (Baloch & Mercer, 1987). Resistance to the DMI's is widespread in Europe, with clear positive cross-resistance between the various products (Gisi *et al.,* 1986). In practice, resistance has reduced the usefulness of azoles as powdery mildew specifics in Europe (e.g. Maumene & Maufras, 1992). Morpholine performance is now variable across Europe and advisory workers have observed a fall off in overall performance in the United Kingdom and France (Gilmour, 1994, Maumene, 1995). Although morpholines continue to give good curative activity, multiple applications are required to give long-term disease control leading to the highest yield benefits (Hardwick *et al.,* 1994). Other broad spectrum compounds, such as the synthetic strobilurins which affect mitochondrial electron transport and amono-pyrimidines which are amino acid biosynthesis inhibitors are currently being developed and are being commercialised and these will help to provide solutions to the control of resistant mildew (Godwin *et al.,* 1992, Heye *et al.,* 1994). DE-795 will add another tool to the armoury of compounds for the control of mildew.

The characteristics of DE-795 a new fungicide under development for the specific control of powdery mildews (Erysiphales), are described in this paper. The resistance profiling and resistance management recommendations for DE-795 are described elsewhere in these proceedings (Hollomon *et al.,* 1996). The biochemical mode-of-action of DE-795 is under investigation; it is not a sterol demethylation inhibitor or a mitichondrial electron transport inhibitor and does not have a mode-of-action corresponding with other currently commercialised fungicides or fungicides known to be under development (DowElanco, unpublished data).

CHEMICAL AND PHYSICAL PROPERTIES

Common Name (ANSI approved):	quinoxyfen
Chemical Class:	quinoline
Chemical Name (IUPAC):	5,7-dichloro-4-(ρ-fluorophenoxy)quinoline
Chemical Name (CA):	5,7-dichloro-4-(4-fluorophenoxy)quinoline
Structural formula:	

Molecular Formula:	$C_{15}H_8C_{12}FNO$
Molecular Weight:	308.1

PRODUCT SAFETY

Mammalian toxicity:

Acute oral LD_{50}	Rat:	>5000 mg/kg
Acute dermal LD_{50}	Rabbit:	>2000 mg/kg
Acute inhalation LD_{50}	Rat:	>3.38 mg/litre
Eye irritation	Rabbit	Mild irritation

Dermal irritation	Rabbit	No irritation
Dermal sensitisation (Buehler)	Guinea pig	No sensitisation
Dermal sensitisation (M&K)	Guinea pig	Sensitiser
Mutagenicity	4 tests	No mutagenic potential
Teratogenicity	Rat, rabbit	No teratogenic potential
Chronic toxicity/Oncogenicity	Rat, Dog }	No oncogenic potential
	Mouse }	No oncogenic potential
Reproduction	Rat	No adverse effects
Toxicity to wildlife:		
Birds (2 species)	LD_{50}	>5620 mg/kg in the food
Fish (2 species)	LC_{50}	>0.2 mg/litre, non toxic
Bees (oral)	LC_{50}	mg a.i./kg honey: >1000
Beneficial Insects (4 species)	IOBC tests	harmless
Environmental Fate:		
Hydrolysis		stable
Photolysis	water	$t_{0.5}$ = 1.5h (June), 22.8h (December)
Mobility	Koc	15415-34985 mg/g non leaching
Soil degradation	DT_{50}	123-454 days

MATERIALS AND METHODS

Laboratory Studies

Wheat cv. Genesis was treated at the at a 1.5-2 leaf stage using a Mardrive sprayer equipped with a 8004 flat fan nozzle applying equivalent to 300 litres/ha spray solution at 300 kPa. Inoculation of *Erysiphe graminis tritici* was carried out by shaking spores from infected plants overhead. For protectant activity inoculation was made 24 hrs following treatment and for eradicant/curative activity inoculation was made 24 hrs before treatment. Trials were also carried out against *Puccinia recondita* and *Mycosphaerella graminicola (Septoria tritici)*; no activity was observed against these diseases.

Field Trials

Trials were of a randomised complete block design with 3-4 replicates and a plot size of 2-3 metres wide by 4-13 metres long giving a minimum treated area of 32m² per treatment. All treatments were applied using a small plot precision sprayer in a water volume of 200- 400 litres/ha. Trials were conducted in France, Germany and the UK. DE-795 was formulated as a 500 g/litre SC, the reference was fenpropimorph formulated as a 750 g/litre EC. In the trials reported in this paper, DE-795 and the reference fungicide were applied only once in the season to measure the length of powdery mildew control. Assessments were made at 14-day intervals; individual leaves were assessed to allow the monitoring of disease protection on the developing plant throughout the season.

RESULTS AND DISCUSSION

Laboratory Characterization

Laboratory studies on DE-795 clearly showed the high degree of protection afforded against mildew attack when the compound was applied as a preventative; this contrasted with the weak curative activity (Table 1). This corresponds with laboratory studies (unpublished) which show DE-795 to be an inhibitor of *Erysiphe graminis* appressorial development.

Table 1. Preventative and curative activity of DE-795 (glasshouse) against wheat powdery mildew (*Erysiphe graminis f.sp. tritici*).

Rate (g a.i./ha)	% Infection	
	Curative	Preventative
0	39.5	17.2
25	26.9	1.4
50	41.8	0.4
75	36.7	0.1
100	33.5	1.1
150	40.5	0.3

Field Efficacy

The evolution of disease protection from an application of DE-795 to winter wheat reflected the characteristic of the compound. In Trials 1 - 3 (Table 2), good protection was observed at 42 days after application on foliage which had emerged after application. In Trial 4, which was treated at BBCH 37, relatively poor mildew control was observed on leaves flag-2 and flag-1, which were present at application.

Table 2. Protection of top leaves from wheat powdery mildew attack (42 days after application).

	% leaf area affected							
	Trial 1		Trial 2		Trial 3		Trial 4	
Leaf category	DE-795	Untr.	DE-795	Untr	DE-795	Untr.	DE-795	Untr.
Flag	0.0	0.0	0.3	1.2	0.0	2.0	0.0	2.3
Flag-1	0.5	1.3	1.5	7.1	0.5	16.7	3.0	8.3
Flag-2	0.4	3.5	0.8	6.8	0.5	18.7	15.0	36.7
Flag-3	0.4	29.5	3.3	11.2	Sen.	Sen.	Sen.	Sen.
Flag-4	Sen.	Sen.	Sen.	Sen.	Sen.	Sen.	Sen.	Sen.
At application:								
Growth stage	BBCH 31		BBCH 31		BBCH31		BBCH37	
Top leaf	F-4		F-3		F-3		F-1	
Powdery mildew	11.5%		14.2%		16.3%		6.0%	

Quinox.=DE-795 at 150 g a.i./ha. Untr.=untreated. Sen.=leaf senesced

From applications made between spring tillering and BBCH32, the weak curative/eradicant activity was reflected in weak control at 14 days after application (DAA). As new foliage appeared on the developing plant (28 to 70 daa) the preventative characteristics of DE-795 were revealed and high levels of disease protection were observed. This is illustrated in Table 3 for winter wheat and Table 4 for winter barley. This long-term protection extended to spring barley on highly susceptible cultivars (such as Golden Promise) which where included in the field trials (Table 5). Fenpropimorph, on all three crops, showed good early activity but did not supply the length of protection against mildew that was supplied by DE-795.

Table 3. Evolution of disease protection in winter wheat against powdery mildew.

Treatment	Rate g a.i./ha	Mean % infection Days after application			
		14	28	42	56
DE-795	150	9.7	4.5	2.5	4.2
DE-795	250	8.8	3.5	1.4	2.8
Fenpropimorph	750	4.0	4.3	5.6	9.3
Untreated		14.7	13.8	13.8	15.5

Disease on top 3 leaves. Results from 31 trials.

Table 4. Evaluation of disease protection in winter barley against powdery mildew.

Treatment	Rate g a.i./ha	Mean % infection Days after application			
		14	28	42	56
DE-795	150	6.8	1.5	1.7	4.2
DE-795	250	6.0	1.6	0.9	3.4
Fenpropimorph	750	2.7	1.3	4.8	7.2
Untreated		12.1	17.3	25.7	29.8

Disease on top 3 leaves. Results from 14 trials.

Table 5. Evaluation of disease protection in spring barley against powdery mildew.

Treatment	Rate g a.i./ha	Mean % infection Days after application			
		14	28	42	56
DE-795	150	4.0	2.6	9.3	18.5
DE-795	250	4.8	1.6	3.0	3.4
Fenpropimorph	750	0.9	9.4	22.7	34.2
Untreated		21.1	56.1	58.4	75.0

Disease on top 3 leaves. Results from 5 trials.

CONCLUSIONS

DE-795 is a new powdery mildew specific fungicide from a new chemical class. It has a good toxicological and environmental profile and is safe to beneficial insects. It shows weak curative/eradicant properties but has a powerful preventative action through the inhibition of appressorial development, in *Erysiphe graminis*. This preventative action can be demonstrated, under field conditions, on newly emerged foliage. For example, from an application of DE-795 made at BBCH 31, mildew protection can be demonstrated on the flag, flag-1 and flag-2 leaves which were not present at application. The protection of new foliage indicates that DE-795 is a mobile preventative fungicide and laboratory trials have demonstrated movement through both systemic movement and acropetal and basipetal movement and through vapour transfer to untreated plants and parts of plants (DowElanco, unpublished).

Another unique feature of DE-795 is the long-term nature of the protection, up to 70 days protection has been recorded on new foliage from a single application of the compound. Although, by virtue of its poor clean-up of treated foliage it does not show outstanding early activity this is more than compensated by the outstanding long-term protection on to newly emerged foliage (Tables 3-5).

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AMPELOMYCES QUISQUALIS, A NEW BIOFUNGICIDE TO CONTROL POWDERY MILDEW IN GRAPES

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ABSTRACT

The use of high levels of pesticides to control powdery mildew disease increases dramatically the cost of grape production to viticulturists throughout the world. Although chemical fungicides are still able to provide adequate control of mildews in most growing regions, fungicide resistance and other concerns have heightened the interest of manufacturers to develop alternative methods of control to replace chemicals.

Ecogen Inc., has developed one such product, AQ10™ biofungicide based on the hyperparasitic fungus *Ampelomyces quisqualis*, or A.q., for the control of powdery mildew disease (*Uncinula necator*) in grapes among other crops. The product was recently registered and launched for commercial sale in the United States. A product has also been submitted for registration in the EU where it is expected for the 1997 season.

A.q. is produced using large-scale fermentation and is formulated as a stable water dispersible granule (WDG) containing fungal spores as the active ingredient. Germinating spores form hyphae that are capable of attacking and penetrating the propagating hyphae of the host via a very specific host-parasite interaction. This process will eventually lead to suppression and/or complete elimination of the powdery mildew pathogen. Results obtained in wine producing regions throughout the world have shown that powdery mildew can be effectively controlled with A.q., if applied to vines at stages where disease incidence is very low and good coverage of the entire vine canopy is attained. The product has also been successfully used in integrated pest management (IPM) programs occurring during bud-break, between bloom and bunch closure and just prior to veraison. The results of representative efficacy trials are discussed.

INTRODUCTION

Powdery mildew is a devastating fungal disease of grapes that causes significant economic losses. Two conventional chemical approaches to control the pest are sulphur in its different formulations and sterol biosynthesis inhibitors (SBI). It has become apparent in recent years that a totally different class of fungicides with a novel mode of action is needed for an effective Integrated Pest Management (IPM) programme. With the discovery of a naturally occurring hyperparasite of powdery mildew, *Ampelomyces quisqualis* (A.q.), biological control has become one option. Essentially through a number of adaptation processes, spores of the hyperparasite have been forced to propagate in a selective growth medium, which led to a cost-effective mass production of such spores to become the active ingredient of the biofungicide discussed. (Hofstein & Fridlender, 1994)

A.q. is formulated as a water dispersible granular (WDG) product using a proprietary process developed by Ecogen. As has been evidenced by vinters worldwide, this formulation is user friendly and meets the needs of growers with regard to shelf life stability at room temperature for more than one year, excellent dispersion in the spray tank and tank-mix compatibility with most chemical insecticides, fungicides and micronutrients.

Field testing of A.q. has included sprays of the product both as stand alone treatments as well as part of an (IPM) approach that includes standard chemicals routinely applied in the grape vine industry. Natural powdery mildew suppression by wild isolates of *Ampelomyces* have also been reported on various crops. (Falk *et al*, 1995a, Sundheim, 1984, Sztejenberg *et al.*, 1989)

Among the most critical issues in the application of A.q. on grapes is the timing of product application. A.q. must be applied prophylactically, or very soon after powdery mildew disease occurs (< 5% incidence is preferable). As powdery mildew is a highly explosive disease in which ascospore release is highly correlated with shifts in weather conditions, the timing of A.q. application is highly dependent on the warnings of disease outbreaks for disease explosion. If unchecked, the disease can cause rapid loss of yield and cannot be readily brought back under control even by fungicides. Such a warning system, often referred to in the United States as an "alarm" system that correlates weather shifts with mildew explosion has been devised (ADCON Telemetry). Through this approach, it has become possible to more precisely time applications of A.q. to achieve high levels of control. The use of an alarm system to time A.q. application will be discussed further below.

In addition to knowing at what stage of mildew development A.q. should be used, vinters need to define precisely at what points in the season they can afford to apply this product vis-a-vis other integrated approaches already being used. Although A.q. has been shown to work effectively at nearly all growing points in the season, (Hofstein & Fridlender, 1994) provided mildew pressure does not become extreme, vinters have numerous considerations which impact their selection of a mildewicide, including vineyard cultivation, disease pressure and nutrient application regimes, to name a few. Among the most critical information is whether A.q. can be applied as a tank mix spray with liquid micronutrients, chemical fungicides and insecticides. Much data in this regard is now available on the effect of tank-mix combinations on spore germination of A.q. (Ecogen, Inc. unpublished data.)

A final area of consideration is the question of how exactly does *A. quisqualis* suppress powdery mildew disease. The answer to this question has not been fully established, but can be addressed both by understanding how the life cycles of these two interesting fungi interface (Abu-Ford *et al.*, 1996), and by observing molecular events on the physiologically active leaf surface that affect the fungus parasite interaction. The fact that *A. quisqualis* evolved as a hyperparasite of powdery mildew in its own right is itself an interesting phenomenon. We will attempt to address the question of the proposed mode of action of A.q. and the opportunities and limitations it creates for use of A.q. as a commercial mildewicide.

MATERIALS AND METHODS

A.q. supply

The WDG formulation of A.q. became commercially available in California following EPA registration in the spring of 1995. The product was applied under a controlled program by winegrape growers in both the United States (California) and Western Europe with high acceptance. The use rate established in both carefully controlled research trials as well as by actual growers was shown to be between 35 and 70 g formulated product/ha per application. A high enough volume of water to achieve thorough canopy coverage was considered essential. Due to the nature of the organism, it required relatively high humidity during the period of spore germination and penetration into the hyphae of powdery mildew. Therefore, it was recommended to apply A.q. late in the afternoon or early in the morning to ascertain that the foliage is still covered with dew while the germination process occurs. The stress due to low relative humidity could be alleviated by creating an optimal microenvironment; this could be attained through the commixing of A.q. with a mineral oil. Hence, mineral oil based Surfactant, AddQ® (registered trademark of Ecogen) was also included in the recommendation as essential tank mix additive for A.q. to provide effective control. The additive has been used in all trials at a rate of 0.3% V/V and no damage to plant tissue has ever been reported.

Standard chemical fungicides

In both research-oriented and grower-applied demonstration trials A.q. and the surfactant have always been compared directly with grower standard chemicals such as sulphur and several different proprietary sterol biosynthesis inhibitor (SBI)-based products, such as products containing myclobutanil. All chemical comparisons were based on grower standards used widely in the winegrape industry. While small-plot research trials are conducted by research scientists using replicated statistically valid research designs, so called DEMO trials are less scientifically precise but allow growers the opportunity to test A.q. adjacent to their standard chemical regime on larger field plots. In all cases, A.q. was applied at the same spray interval as the chemical standard, usually 14 days between treatments. In some cases, A.q. was combined with micronutrients, such as zinc, or chemical fungicides, such as copper used for other fungal diseases.

Timing of A.q. application

In order to identify the optimal window for application of A.q. during the growing season, three application regimes were evaluated including: from bud-break to bloom, from bloom to bunch-closure, and just prior to veraison. It is believed, however, that A.q. can actually be applied season-long in the majority of instances. The three application points mentioned above were based purely on the phenology of the vines in question while in other cases a warning or "alarming" system was used by adaptation of the ADCON telemetry unit to a risk assessment program designed at U.C. Davis (Weber *et al.*,1996)

Disease assessment

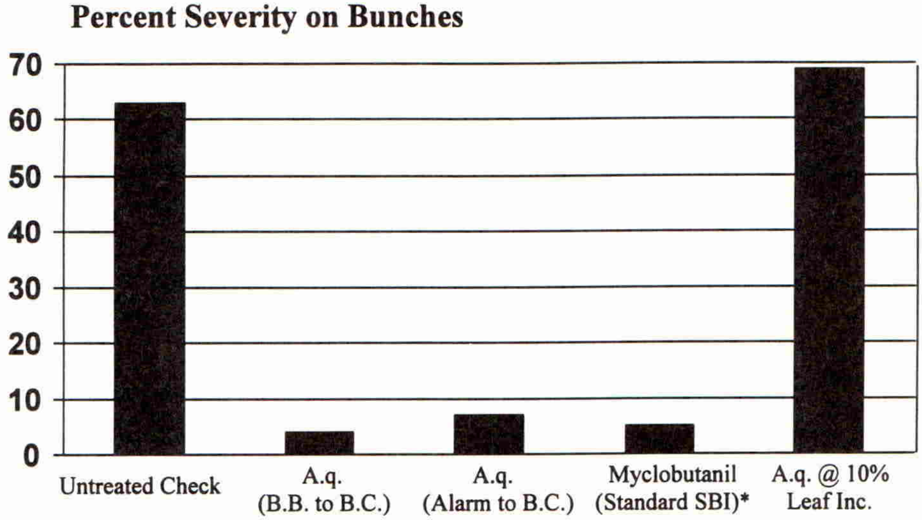
Disease assessments are critical to the understanding of how A.q. works. Readings ideally should be made on a superficial basis weekly. This not always being possible, all experimental trials had at least two assessments at critical points in the season. This included an estimate of both disease incidence (qualitative assessment of number of leaves or bunches infested) and disease severity (quantitative estimate of level of infection on leaves or bunches). Only rarely were microscopic observations made using specialized staining techniques developed by Ecogen to observe hyperparasitism.

RESULTS

Small-plot research trials

Early trials were conducted to establish use rates for A.q. applied as a stand alone regime at 35-70 grams formulated product/ha on a schedule of once every 10-14 days (data not shown). In these trials, and later on within the IPM scheme, A.q. was used in tank mix with 0.3% V/V surfactant. Given the limited knowledge of how best A.q. works and to allow growers more flexibility in timing of A.q. incorporation into the IPM scheme, several options were considered. Trials, therefore, included three approaches as follows: (1) Application of A.q. alone starting at bud-break (prior to significant disease outbreaks) and continuing on a 10-14 day schedule through bunch closure; (2) Application of A.q. based upon the ADCON warning alarm system that is set off under conditions expected to lead to powdery mildew explosion; and (3) Application of A.q. only after disease incidence on leaves rises above 10% allowing powdery mildew to take hold before the hyperparasite is applied. The results of these three regimes as compared to an untreated check and a chemical standard regime are shown in Fig. 1 below. Only disease severity is considered here as results of assessments for disease incidence are consistent with assessments shown for disease severity.

Figure 1. Percent severity assessed on Chardonnay grape bunches following A.q. application at period of ①bud-break (BB) to bunch-closure (BC); ②ADCON alarm to bunch-closure (BC); and ③initial A.q. application at >10% leaf incidence of powdery mildew. These are compared to a common grower standard of 2x sulphur followed by myclobutanil.

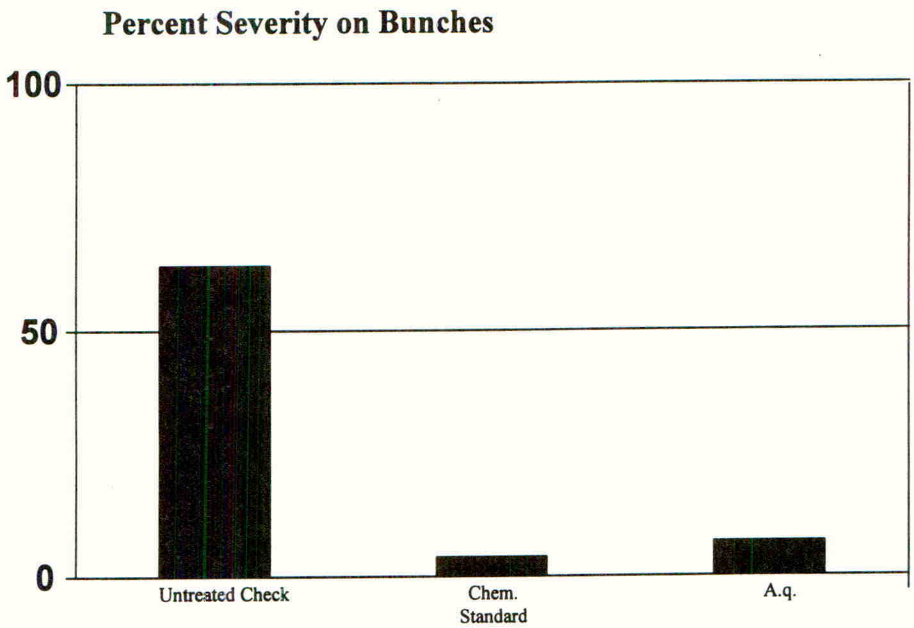


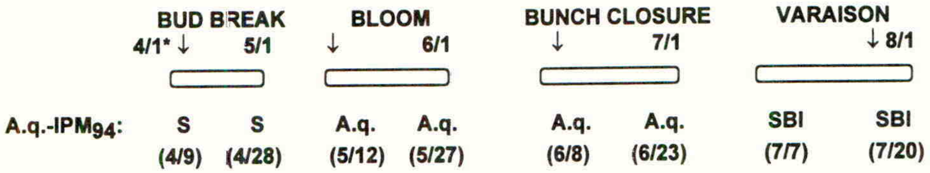
* After 2x Sulfur

As can be seen from the above results, A.q. performed well and equivalent to the grower's standard regime (included 2 early-season sulphur applications followed by sulphur/SBI mixtures or SBI's alone for the remainder of the season) providing A.q. was applied when disease incidence was still low (i.e. below 10% leaf infection or incidence). In the case where disease incidence exceeded 10% prior to starting the A.q. regime, A.q. failed to control the disease. The extent of disease control was similar between when sprays were initiated at bud-break and when they were made at the time of the alarm. Using the alarm system, one A.q. application was deleted as the alarm did not occur until approximtely 3 weeks following bud break.

A second series of small-plot trials were conducted to evaluate the efficacy of A.q. when included in an IPM scheme after early season sulphur and prior to late season standard chemicals (e.g. myclobutanil). Such an approach has been favored by a group of growers in Europe, S. Africa and Australia where sulphur had to be displaced during the period of bloom to bunch-closure. Figure 2 depicts a common scheme (representative of the 1995 program in California) where A.q. was compared to growers' chemical standard regime.

Figure 2. Percent severity on grape bunches following four A.q. applications at 12-14 day intervals during a period of bloom to bunch closure; A.q. is compared to a standard regime in which only chemicals were applied and to an untreated check.



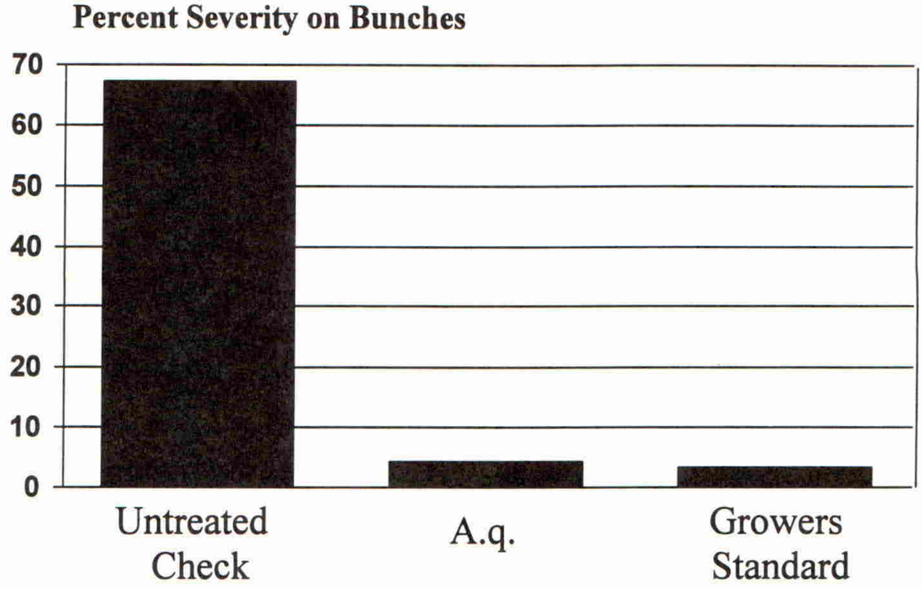


This IPM approach, as shown in Figure 2, provides the flexibility to use SBI fungicides during a prolonged period of grapevine development without jeopardizing the permissible use rates of the latter and helped to reduce the risk of developing fungicide resistance.

Demonstration (DEMO) trials

A successful small-plot programme led to the next stage where product was offered to growers for application on large (2 - 8 ha) demonstration plots in comparison to their own a standards. In this programme, A.q. was applied 3-4 times at 10-14 day intervals during a period from prior to bloom to bunch-closure. The results were compared to small untreated blocks in each plot. Disease severity was assessed following the last A.q. treatment and the results are presented in Figure 3 below.

Figure 3. Percent severity assessed and averaged over 17 individual DEMO sites.



Control of powdery mildew disease within the DEMO program containing A.q. was comparable to that attained with the grower's standard regime. The grower's stndard regime usually employed early-season sulphur followed by SBI chemicals beginning around bloom though veraison.

DISCUSSION AND CONCLUSIONS

The main impetuses for the development of the biofungicide A.q. have been the environmental safety of this biofungicide as well as the rapidly developing resistance of powdery mildew to SBI fungicides. Through Ecogen's discovery of a production process for this proprietary strain of *A.q.* in submerged fermentation, A.q. offers an alternative to season-long use of a chemical application regime. The results have shown that A.q. can provide an effective alternative to both sulphur and SBI fungicides provided growers do not allow disease pressure to exceed thresholds above which A.q. can no longer bring disease back under control. Low level disease incidence can be assured if applications are made prior to bud break or if the alarm system is used which provides the grower more latitude with regard to timing his applications. As long as <10% leaf incidence is observed, A.q. can effectively be incorporated into an IPM scheme at any stage. In fact, results in 1996 showed that A.q. can even be used as a pre-veraison treatment (data not shown). Use of A.q. just prior to veraison is very attractive to vinters that would like to limit the use of chemicals, such as sulphur and SBI fungicides during this period to reduce residues on the berries.

Another possible approach would be the use of A.q. as a post-harvest treatment. This approach has been proposed by some, based upon the scientific observation that *A.q.* may be able to overwinter within the cleistothecia of powdery mildew fungus. (*Cortesi et al.*, 1994; Falk *et al.*, 1995b) This concept will soon be tested as an approach to alleviate pressure due to primary infection that is difficult to control early-season using conventional treatments. This, together with the hypothesis that the interaction of A.q. with the growing hyphae of powdery mildew preserves the vitality of chloroplasts (*Abo-Foul et al.*, 1996), may shed light on the delicate balance that exists in nature between the fungal pest and its hyperparasitic antagonist. A better understanding of the interactions at the molecular level will provide clues as to how A.q. could be further improved so as to attain season-long disease control.

In conclusion, the data shows that A.q. can be effectively used in an integrated control programme to provide disease control while still reducing chemical residues on the crop and in the environment. A.q. provides disease control via the process of hyperparasitism. This may sound contradictory given that the recommended use pattern for the product is prior to mildew disease being present, i.e. prophylactic application. The results clearly show, however, that even at very low disease incidence, the hyperparasite can work effectively and propagate. It may also persist, for at least a short time, even prior to the disease actually occurring.

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CGA329351: INTRODUCTION OF THE ENANTIOMERIC FORM OF THE FUNGICIDE METALAXYL

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ABSTRACT

CGA329351 or metalaxyl-M is the more active of the two enantiomers of the phenylamide fungicide metalaxyl; metalaxyl is currently registered in more than 80 countries with uses on more than 60 crops. CGA329351 is the first enantiomeric form of a fungicide introduced into the market.
CGA329351 when used as seed-treatment, soil treatment or foliar application against fungi of the order *Peronosporales* provides the same excellent level of efficacy as metalaxyl but at half the application rate. The introduction of CGA329351 contributes towards further risk reduction for a compound with an excellent safety profile for consumers, applicators and the environment. The reduction in environmental loading in combination with faster soil degradation are factors involved in this reduction of risk.

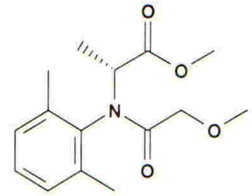
INTRODUCTION

Since its introduction into the crop protection market in 1977, metalaxyl has been recognized as an impressive technical innovation in the management of plant diseases involving members of the Oomycete class.
CGA329351 is the (R)-enantiomer of metalaxyl or metalaxyl-M. In laboratory tests, CGA329351 proved to be the more active of the two enantiomers (Hubele *et al.*, 1982; Moser and Vogel, 1978). CGA329351 is being developed by Ciba-Geigy as a foliar fungicide, as a soil fungicide and as a seed treatment and will be marketed under various trademarks including 'Ridomil Gold' and 'Apron XL'. The sales formulations contain CGA329351 at half the metalaxyl use rate, although several fold higher activity of CGA329351 compared to metalaxyl has been observed under certain conditions. The use rate was selected as a result of the limited biological data package available in relation to the broad commercial use targeted, as well as a different level of knowledge in formulation technology for the liquid active ingredient CGA329351 compared to the solid metalaxyl. This paper describes the properties of CGA329351, the field performance of CGA329351-based formulations on several economically important crops and diseases, the environmental and safety advantages of CGA329351 and its registration status.

CHEMICAL AND PHYSICAL PROPERTIES

Common name :	metalaxyl-M
Chemical class :	phenylamide
Chemical name *(IUPAC)* :	(R)-methyl N-(2-methoxyacetyl)-N-(2,6-xylyl)-DL-alaninate

Structural formula:



Optical rotation: negative (minus)
Molecular formula : $C_{15}H_{21}NO_4$
Molecular weight : 279.3
Appearance at 25°C: pale yellow to light brown viscous liquid
Boiling point : thermal decomposition occurs at about 270°C
Solubility in water at 25°C : 26 g / litre
Partition coefficient n-octanol/water : log P_{OW} = 1.71

FORMULATIONS

For soil uses in Europe, CGA329351 will be available as a granule formulation as well as an emulsifiable concentrate; additional formulations, including a mixture with PCNB, will be introduced in the USA. For foliar applications, CGA329351, formulated in mixtures with other fungicides, will be commercialised as a wettable powder, as a water dispersible granule, as an emulsifiable concentrate as well as a flowable formulation. For seed treatment, different formulations including flowable concentrates and emulsifiable suspensions are in development.

KEY BIOLOGICAL FEATURES

Like metalaxyl, CGA329351 is a systemic, apoplastically transported fungicide, highly active against fungi of the order *Peronosporales.* Metalaxyl inhibits the fungus by selectively interfering with the synthesis of ribosomal RNA. A comparative study of the biochemical and physiological effects of the stereoisomers of metalaxyl indicated that the (R)- and the (S)-enantiomers have the same mode of action but show considerable differences in the effectiveness in reaching or binding to the receptor (Fischer and Hayes, 1985). As the resistance mechanism is strictly related to the biochemical site of action of metalaxyl, cross-resistance between CGA329351 and metalaxyl as well as other phenylamide fungicides is expected to occur.

FIELD EXPERIMENTS

Trials were carried out in 1993-95 with the objective to generate bridging bioefficacy data comparing field performance of CGA 329351- and metalaxyl-based products for registration purposes. All work reported is from fully replicated small plot trials (with 3 to 6 replicates) conducted in randomised complete block design.

Biological activity as a foliar fungicide

Trials reported were carried out on grapes, potatoes and tobacco with 3 plot sizes of 10 to 75 m^2 and spray volumes from 150 to 1500 litres/ha. The products evaluated and compared contained 4% CGA 329351 + 64% mancozeb and 8% metalaxyl + 64% mancozeb. Phenylamide-based products were used protectively for the first 3 to 5 sprays in 10 to maximum 14 day intervals, and were followed by mancozeb applied weekly at the local use rate. Disease assessments were made by estimating the percentage of leaf (and bunch for grapes) surface infected.

Trials data (Table 1) show that performance of CGA 329351 at half-rate in the mixture with mancozeb was at least equal to that of the mixture containing metalaxyl at its use rate for control of potato late blight (*Phytophthora infestans*), grape downy mildew (*Plasmopara viticola*) and tobacco blue mold (*Peronospora tabacina*).

Table 1. Control of *P. infestans* on potatoes, *P. tabacina* on tobacco and *P. viticola* on grapes in Europe or Indonesia.

Pathosystem	Trial location	Number of trials	% infected leaf area Untreated	Metalaxyl+MZ	CGA329351+MZ
P. infestans potatoes	Northern Europe	7	84	4 *	3.1 *
	Southern Europe	5	39	2.9 *	2.6 *
	Indonesia	2	75	5.9 *	5.5 *
P. tabacina tobacco	Italy	3	21	4 **	2.1 **
P. viticola grapes	Northern Europe	3	29	2.9 ***	4.9 ***
	Southern Europe	4	31	3 ***	3.3 ***
			% infected bunch area		
	Southern Europe	5	31	5.7 ***	3.2 ***

metalaxyl+MZ at *: 200+1600g a.i./ha, **: 24+192g a.i./hl, ***: 20+160g a.i./hl and CGA329351+MZ at *: 100+1600g a.i./ha, **: 12+192g a.i./hl and ***: 10+160g a.i./hl

Biological activity as a soil fungicide

Table 2. Performance of CGA329351 compared to metalaxyl against soilborne pathogens.

Pathosystem	Country / trial identification	Untreated	Treatment Metalaxyl	CGA329351
		% biomass (6 DAT) / mean of 2 trials		
Pythium aphanidermatum / brassicas	Malaysia / MALES03595 MALES03695	27	96 *	95 *
		stand (plants / plot) (14 DAT)		
Pythium ultimum / cotton	USA / USA3F0294	155	193 **	206 **
		% disease control (70 DAT)		
Phytophthora nicotianae / tobacco	USA / USA7F60294		88 ***	98 ***

metalaxyl applied at *: 500g or ***:1121g a.i./ha compared to CGA329351 at *: 250g or ***: 561g a.i./ha and **: metalaxyl+terrachlor at 70+1121g a.i./ha compared to CGA329351+terrachlor at 35+1121g a.i./ha

In 2 replicated trials on leafy brassicas in Malaysia (plot size: 1 m^2), application of fungicide was done prior to planting by soil drenching (1 litre/m^2) followed by soil incorporation. Disease assessment was made by estimating visually the percentage of biomass compared to the best plot. In USA, in a replicated cotton trial (plot size: 2 rows x 20 ft), fungicides were applied in furrow prior to seeding (water volume: 95 litres/ha), whereas in a replicated tobacco trial (plot size: 24 m^2; water volume: 285 litres/ha) broadcast application of fungicides was made prior to transplanting. The products evaluated and compared were CGA329351 240EC (USA) or 480EC (Malaysia) and metalaxyl 240EC.
Trial results presented in Table 2 show that similar efficacy is achieved when CGA329351 is applied at half the metalaxyl rate against the different pathogens tested.

Biological activity as a seed treatment

Trials presented compare metalaxyl as 35SD with CGA329351 as LS350 or WP45. Applications were made with either a Hege 11 seed treater (*Pythium ultimum*/maize) or by mixing the diluted product with seed in a plastic bag (downy mildew/maize). The replicated trials on *P. ultimum*/maize were carried out under glasshouse conditions with 100 seeds / rep sown into sterilised soil inoculated artificially. Counts of emerged plants were made 21 - 24 days after planting. Downy mildew trials were carried out under field conditions in Indonesia on sites with natural *P.maydis* infestations (plots size: 3 m^2) and assessed at regular intervals during disease development.
Trials showed that CGA329351 applied at half the recomended rate of metalaxyl gave biological activity equivalent to the racemate for control of the two diseases (Table 3).

Table 3. Control of *P. ultimum* and *P. maydis* on maize.

	Rate g ai/100kg seed	*P.ultimum*/Maize No. of plants** (mean of 4 trials) 21-24 DAP	*P. maydis*/Maize % plants infected (mean of 2 trials) 12 DAP	31 DAP
Untreated	-	28.5	10.5	62.5
Metalaxyl	35	92.5	0 *	0 *
CGA329351	17.5	94.4	0 *	0 *

*: metalaxyl at 105g a.i./100kg seed and CGA329351 at 52.5g a.i./100kg seed ** Maximum = 100
DAP: days after planting

Crop tolerance

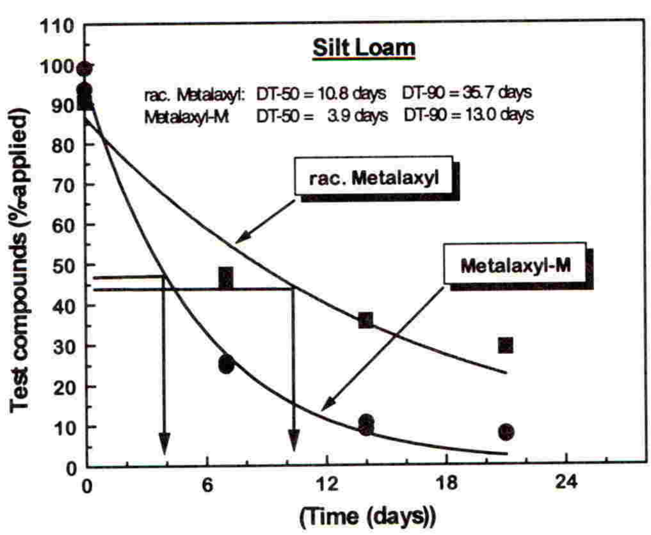
Crop tolerance of CGA329351-based products applied at the recommended use rates was good in all trials with the different application methods (foliar, soil, seed treatment) and on all crops evaluated, as it was the case for the corresponding metalaxyl-based products. Metalaxyl demonstrates good crop safety on more than 60 crops. It is expected that CGA329351-based products are well tolerated on the same target crops when used according to the recommendations.

ENVIRONMENTAL AND SAFETY ADVANTAGES

All safety and registration studies completed with metalaxyl also involved the R-enantiomer, as metalaxyl consists of 50% of this isomeric form. This is particularly relevant for the toxicology database, as metalaxyl has one of the best toxicological profiles of any registered disease control plant protection product. For example, EPA has classified metalaxyl as an 'E' class oncogen (i.e., no evidence of carcinogenic potential) and the profile of metalaxyl reveals a generally low order of acute and dermal toxicity and no mutagenicity hazard. Studies done with CGA329351 show the toxicological properties of the isomeric form are virtually identical to those of the racemate, particularly for chronic exposures. The reference dose to be utilized to calculate a safety factor for dietary exposure was found to be the same for CGA329351 and metalaxyl. There is an increase in the acute eye toxicity seen with CGA329351 technical that leads to a "Danger" signal word classification (compared to a "Warning" for metalaxyl technical).

Slow degradation is expected to occur in the case of soils with low biological activity as it has been demonstrated that metalaxyl and CGA329351 are primarily degraded via biologically based routes; in such situations, chemical hydrolysis on the soil surface dominates as the primary route of degradation. In studies with biologically active soils, CGA329351 consistently degraded faster by a factor of up to 2.7 when compared with metalaxyl (Fig. 1). The rapid and unexpected, enantiospecific biological degradation is considered an important factor in the risk reduction potential of CGA329351. Combined with the lower application rate, this reduction in soil half-life means that CGA329351 poses a reduced risk of contamination to water sources.

Figure 1. Rate of degradation of metalaxyl and CGA 329351 in fieldfresh soil (silt-loam) under laboratory conditions.



DT: disappearance time

In side-by-side field trials comparing residues of CGA329351 and metalaxyl on different crops, a consistent ratio of decreased residues matching the reduction in use rate has been demonstrated. Therefore, the result of the registration of CGA329351 will be a significant reduction in the dietary exposure for consumers.

The reduction in application rate also allows for a reduction in exposure to flora and fauna that occur in the agroecosystem. Given the anticipated level of exposure and the proposed use pattern of CGA329351 formulations, no unacceptable impact on beneficial insect populations are anticipated with the field use of this product.

Along with the reduction in the field use rate, there will be less waste being generated, less energy consumed, and less raw material consumption associated with the production of CGA329351.

REGISTRATION STATUS

CGA329351 and 13 end-use products containing this active ingredient were registered by EPA on March 6, 1996. The product was introduced to the US market in 1996.

During the registration process for CGA329351 in the United States, CGA329351 was declared a "Reduced Risk" product by EPA. This program is designed to provide for a higher review priority for products carrying this designation, providing for faster registration approvals for those products that have favourable environmental profiles in comparison to currently registered products.

Inclusion of CGA329351 in Annex I within the EU was initiated with the submission of the dossier in the first quarter, 1996.

GENERAL DISCUSSION

Biological tests show that fungicidal activity of racemic metalaxyl derives primarily from CGA329351. This basic property offers the opportunity to reduce the use rate of metalaxyl without any loss of disease control.

In those regulatory situations where "use reduction" is a major policy target for plant protection products, we feel it is important to emphasize that introduction of CGA329351 is aimed at **risk reduction**. However, since the database for CGA329351 reveals that in all aspects it is, at a minimum, equivalent to metalaxyl and since CGA329351 is an isomeric form of metalaxyl, this is one situation where risk reduction is equivalent to use reduction.

ACKNOWLEDGEMENTS

The authors would like to thank all their colleagues in Switzerland and in the CIBA Group Companies who have contributed to the data presented in this paper.

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KWG 4168: A NOVEL FOLIAR FUNGICIDE WITH A PARTICULAR ACTIVITY AGAINST POWDERY MILDEW

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ABSTRACT

KWG 4168 is a systemic foliar fungicide currently being developed for use mainly in cereal crops. The compound acts as a sterol biosynthesis inhibitor, providing both a rapid initial effect and prolonged activity by means of its protective, curative and eradicative properties.

Used as a foliar spray in wheat and barley KWG 4168 exhibits excellent control of powdery mildew (*Erysiphe graminis* f.sp. *tritici* and f.sp. *hordei*). In addition, a good effect is evident against rust diseases (*Puccinia* spp.) of wheat and barley, *Rhynchosporium secalis* and *Pyrenophora teres*. Thus, the spectrum of activity is broader than usually known from other amines and consequently KWG 4168 may be applied either alone, or in combination with other fungicides in order to complement their spectrum of activity.

The systemic properties and the mode of action of KWG 4168 are described, along with the sensitivity of *E. graminis* f.sp. *tritici* to this compound.

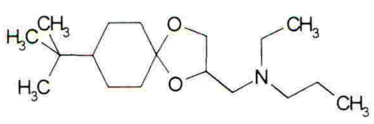
INTRODUCTION

KWG 4168 from the new chemical class of Spiroketalamines was discovered in 1987 and has been developed as a foliar fungicide for use in cereals. Commercial introduction into the main European markets is scheduled for 1997-98. This paper describes its chemical properties, mode of action, fungicidal spectrum of activity and performance in the field.

CHEMICAL AND PHYSICAL PROPERTIES

Common name (ISO proposed):	Spiroxamine
Chemical class:	Spiroketalamine

Structural formula:



Chemical name (CA):	8-(1,1-Dimethylethyl)-N-ethyl-N-propyl-1,4-dioxaspiro[4.5]decane-2-methanamine

Molecular formula: $C_{18}H_{35}NO_2$

TOXICOLOGY

Acute oral rat:	male: LD_{50} ~595 mg/kg b.w.
Acute dermal rat:	male: LD_{50} > 1600mg/kg b.w.
Acute inhalation rat:	male: LC_{50} ~ 2772 mg/kg m^3
Eye irritation rabbit:	non-irritant
Skin irritation rabbit:	irritant
Genotoxicity (5 tests):	no genotoxic potential
Reproductive toxicity:	no specific effects
Birds:	LD_{50} = 565 mg/kg b.w.
Earthworms:	LC_{50} ≥ 1000 mg/kg dry weight substrate
Fish (rainbow trout):	LD_{50} (96h) = 18.5 mg/litre
Bees:	no risk to bees

MODE OF ACTION AND SYSTEMICITY

KWG 4168 was designed in a synthesis programme for new sterol biosynthesis inhibitors (SBIs) (Berg *et al.*, 1993). The investigations on the mode of action of KWG 4168 in comparison to morpholines and piperidines were carried out using *Ustilago avenae*, due to the difficulties in handling *Erysiphe graminis*. The sterol pattern after application of KWG 4168 is shown in Table 1.

Table 1. Sterol pattern of *Ustilago avenae* after application of KWG 4168.

	Sterol composition (%)			
Sterol	Untreated	KWG 4168	Fenpropidin	Fenpropimorph
Ergosterol	64	9	9	4
$\Delta^{5,7}$-Ergostadienol	36	2	-	-
Δ^{7}-Ergostenol	-	5	11	-
$\Delta^{8,14}$-Ergostadienol	-	84	77	14
Δ^{8}-Ergostenol	-	-	-	51
$\Delta^{8,22}$-Ergostadienol	-	-	-	14
$\Delta^{5,8,22}$-Ergostatrienol	-	-	3	17
Sterol content (µg/mg d.m.)	1.26	4.50	6.83	2.71
Growth (%)	100	50	59	47

(- : not detected)

The mode of action of KWG 4168 against *U. avenae* is similar to that of fenpropidin: their main target is sterol Δ^{14}-reductase. From more detailed investigations with additional fungi, using the four isomers of KWG 4168, additional activities were detected against sterol $\Delta^{8} \rightarrow \Delta^{7}$-isomerase, squalene synthase and squalene cyclase.
The systemic properties of KWG 4168 were examined using radio-labelled compound. KWG 4168 readily penetrates into the leaf tissue followed by an acropetal translocation to the leaf tip. In contrast to other highly mobile compounds, which accumulate at the leaf tip, KWG 4168 shows a very uniform distribution within the whole leaf.

BIOLOGICAL PROPERTIES

KWG 4168 has been intensively tested for activity against the major fungal pathogens in cereals. Plot size in field trials varied from 12.5 - 25 m^2, using 3-4 replicates. Most of the trials were conducted in UK, France and Germany.
As can be seen from Table 2, the main strength of KWG 4168 is its control of *E. graminis* in wheat and in barley. Good results were also obtained against *Puccinia* spp., *Pyrenophora teres* and *Rhynchosporium secalis* with some effects against *Mycosphaerella graminicola* and *Leptosphaeria nodorum* reported from many trials. Thus, the spectrum of activity of KWG 4168 is broader than usually known from other amines.
The Tables 3 to 6 demonstrate the efficacy of KWG 4168 in comparison with standard compounds, predominantly from the chemical classes of morpholines and piperidines. Against powdery mildew and various rust diseases of wheat and barley the compound is at least as effective as the corresponding reference product; with regard to *R. secalis* and *P. teres*, KWG 4168 shows a similar level of activity to that of various sterol demethylation inhibitors (DMIs) and DMI-mixtures (Table 5).

Table 2. Spectrum of activity of KWG 4168.

Crop	Rate(g a.i./ha)	Excellent activity	Good activity	Some effects
Wheat	500-750	*Erysiphe graminis*	*Puccinia recondita* *Puccinia striiformis*	*Leptosphaeria nodorum* *Mycosphaerella graminicola*
Barley	500-750	*Erysiphe graminis*	*Puccinia hordei* *Pyrenophora teres* *Rhynchosporium secalis*	

In glasshouse tests the curative and eradicative properties of KWG 4168 were comparable to those of morpholines and piperidines (Table 7). However, field trials showed KWG 4168 to give superior results where applications were made shortly after establishment of a mildew infection.

Table 3. Efficacy against *Erysiphe graminis*, 1992-94.

Treatment	Rate (g a.i./ha)	Efficacy (% Control)	
		wheat (59)	barley (9)
KWG 4168	750	81	85
Fenpropimorph	750	75	-
Fenpropidin	750	-	82
Untreated (% disease)	-	24	31

( ) = number of trials.

Table 4. Efficacy against *Puccinia* spp., 1992-94.

Treatment	Rate (g a.i./ha)	Efficacy (% Control)	
		wheat (16)	barley (12)
KWG 4168	750	76	76
Fenpropidin	563	65	60
Untreated (% disease)	-	33	38

( ) = number of trials.

Table 5. Efficacy against *Rhynchosporium secalis* and *Pyrenophora teres*, 1993-94.

Treatment	Rate (g a.i./ha)	Efficacy (% Control)	
		P. teres (21)	*R. secalis* (28)
KWG 4168	750	66	67
Reference (various DMIs and DMI-mixtures)*	as registered	61	73
Untreated (% disease)	-	28	21

( ) = number of trials

* = tebuconazole, flusilazole + carbendazim, propiconazole + fenpropidin, prochloraz + carbendazim

Table 6. Efficacy of KWG 4168 with tebuconazole against *Mycosphaerella graminicola*, (1994, 7 trials)

Treatment	Rate (g a.i./ha)	Efficacy (% Control)
KWG 4168 + Tebuconazole	375 + 200	85
Tebuconazole	250	80
Untreated (% disease)	-	37

Table 7. Eradicative properties of KWG 4168 against *Erysiphe graminis* f.sp. *tritici*.

Treatment	Rate (g a.i./ha)	Efficacy (% Control)		
		3 DAT	4 DAT	6 DAT
KWG 4168	750	50	79	75
Fenpropimorph	750	33	58	55
Fenpropidin	563	22	58	69
Untreated (% disease)	-	75	75	91

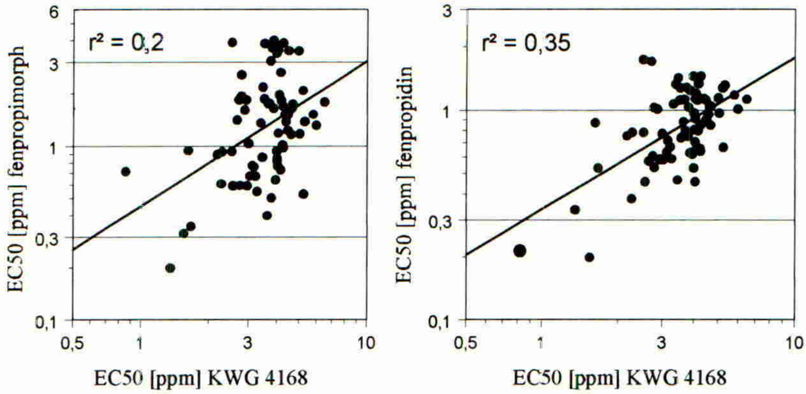
application 4 days after inoculation, glasshouse-test

BASELINE SENSITIVITY AND CROSS RESISTANCE

Baseline sensitivity of wheat powdery mildew to KWG 4168 was investigated over two years in the major wheat growing areas of Europe with the aid of a mobile spore trap (Felsenstein, 1994a). Variation of ED_{50} values was small between regions of northern Europe and between the two years of observation. As described already for fenpropimorph (Felsenstein, 1994b), tests with KWG 4168 showed that mildew isolates from Italy and Spain exhibited a higher sensitivity than isolates from northern parts of Europe. However, whereas for fenpropimorph differences were >10 between southern and northern European isolates, the differences for KWG 4168 were only < 3.5.

The cross resistance pattern of KWG 4168 against DMI-fungicides and the morpholines / piperidines was tested with a method described by Schulz (1991). As expected from the mode of action studies, no cross resistance of KWG 4168 could be found to DMIs (unpublished results). However, a positive cross resistance with morpholines and piperidines has been detected. As demonstrated in Fig. 1, in all local populations of wheat powdery mildew tested so far, relatively low correlation coefficients ($r^2 < 0.4$, not significant) were found. Only when populations from Italy and Spain were combined with those from northern parts of Europe did the correlation coefficient increase to values > 0.7.

Figure 1. Cross resistance study between KWG 4168, fenpropimorph and fenpropidin with *Erysiphe graminis* f.sp. *tritici*. Fungal isolates originated from one location in Germany (Laacher Hof).



CONCLUSIONS

KWG 4168, a systemic foliar fungicide of a new chemical class, shows especially good activity against powdery mildew of wheat and barley. The data presented demonstrate the relatively broad spectrum of activity. It is, therefore, well suited for use either alone, or for complementing the activity of other fungicides by tank-mixing or in co-formulations. Since KWG 4168 is not a DMI-fungicide it will contribute as another option to resistance management.

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PLANT ACTIVATOR CGA 245704: AN INNOVATIVE APPROACH FOR DISEASE CONTROL IN CEREALS AND TOBACCO

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ABSTRACT

CGA 245704 is the first compound of a new generation of crop protection agents which activate plant defense mechanism called "systemic activated resistance" (SAR). This particular form of plant resistance can be activated by biotic and abiotic agents and results in a systemic protection of the entire plant against a spectrum of diseases caused by fungi and bacteria. CGA 245704 copies this natural biological phenomenon and provides reliable and commercially acceptable protection in several crops against a number of diseases.

In cereals, CGA 245704 at 30 g a.i./ha provides a long lasting protection against *Erysiphe graminis* with a single application at GS 25-32. Partial protection against *Septoria* spp. and *Puccinia* spp. can be achieved. Good protection of tobacco against *Peronospora hyoscyami* f. sp. *tabacina* is obtained with 12 g a.i./ha and repeated applications. Mixtures with conventional fungicides are proposed to control established disease infections and to extend the spectrum of activity. With its new technology, CGA 245704 offers an additional, new way in crop protection.

INTRODUCTION

The natural phenomenon of resistance development in plants in response to pathogen infection was first recognized in 1901 by Ray & Beauverie. Detailed analysis of induced resistance started only in the 1960s. In 1975, Professor J. Kuc demonstrated the biological phenomenon of "systemic activated resistance" (SAR) in experiments with cucumbers. However, the biological SAR occurred only sporadically in nature and could not be used for practical crop protection.

This fascinating technology, however, was further investigated by Ciba-Geigy with the goal of identifying molecules that allow a controlled induction of SAR. After an period of intensive research, CGA 245704 was discovered and developed, offering a new way in crop protection.

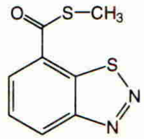
CGA 245704 is developed for the protection of cereals, rice, tobacco, banana and certain vegetable crops against phytopathogenic diseases caused by fungi and bacteria (Ruess *et al.*, 1995). In 1996, the product has been introduced in Germany under the trade name Bion® 50 WG and in Switzerland as Unix Bion® 63 WG for the control of *Erysiphe graminis* in wheat.

This paper describes the properties of CGA 245704 and its performance against diseases in cereals and tobacco under European conditions.

CHEMICAL AND PHYSICAL PROPERTIES

Product category: Plant Activator

Structural formula:



Code number: CGA 245704

Chemical name (IUPAC): Benzo(1,2,3)thiadiazole-7-carbothioic acid-S-methyl ester

Molecular formula: $C_8H_{16}N_2OS_2$

Molecular weight: 210.3

Appearance at 25°C: white to beige odourless powder

Melting point: 132.9 ^{0}C

Vapour pressure at 25°C: 4.6 x 10^{-4} Pa

Solubility in water at 25°C: 7.7 mg/litre

Solubility in organic solvents at 25°C:
n-hexane 1.3 g/litre, toluene 36 g/litre, n-octanol 5.4 g/litre, acetone 28 g/litre, dichloroethane 160 g/litre

Partition coefficient at 25°C: log P_{OW} = 3.1 (n-octanol/water)

TOXICOLOGY

Acute oral LD_{50} rat: >2000 mg/kg

Acute dermal LD_{50} rat: >2000 mg/kg

Acute inhalation LC_{50}: >5000 mg/m^3

Skin irritation rabbit: non-irritating

Eye irritation rabbit: non-irritating

Sensitization: sensitizing potential of a.i.

Mutagenicity: no mutagenic potential

Teratogenicity: of no risk for humans

Cancerogenicity: no cancerogenic potential

MATERIALS AND METHODS

Life cycle studies. Tobacco cv. Xanthi was cultivated in TKS 2 standard soil for 5 weeks under standard greenhouse conditions at 22°C. CGA 245704 (WP 25) was applied 4 days protectively. For inoculation, a sporangial suspension of *Peronospora hyoscyami* f. sp. *tabacina* of 10000 sporangia/ml was prepared in tap water and each leaf was inoculated each with 6 drops of 10 µl. The inoculated plants were incubated for 24 h at 100% RH and 20°C in the dark and then they were transferred to 90% RH and a light period of 14 h until further processing. Light microscopic evaluation was carried out 24 and 48 h after inoculation.

Tobacco field trials were laid out in randomized complete blocks with 4 (-3) replicates. Plot size varied from 10-15 m^2 or about 60 plants/plot. All trials were sprayed protectively with first application 16-24 days after transplanting with a total of 3-6 applications. Spray volumes were 600-1500 litres/ha. A visual assessment of the percentage infected leaf area

was made for the plot as a whole in Italy; in French trials, % infected plants and number of infected leaves were also recorded.
Cereal field trials were carried out in randomized complete block system with 4 replicates. Plot size was 10-25 m^2. All trials were treated with a precision sprayer and spray boom using spray volumes of 200-500 litre water/ha. Visual assessments of the infected leaf area were made in percent for the plot as a whole. Growth stages (GS) are described according to BBCH scale. Products: CGA 245704 was tested in field trials as 50% water dispersible granule (WG50). In cereals, mixtures of CGA 245704 with cyprodinil or fenpropidin were tested. In tobacco, mixtures with metalaxyl or metalaxyl-M (the (R)-enantiomer of metalaxyl) were evaluated.

BIOLOGICAL ACTIVITY

Mode of action

CGA 245704 and its metabolites have been tested *in vitro* against 19 phytopathogenic fungi and bacteria and showed no significant toxic effect at 57 ppm a.i. However, by induction of the plant's own defense mechanisms, the compound provides a strong protection of plants against pathogens.
Most of the inducible mechanisms are localized at the site of attempted microbial infection, where the plant responds first with localized cell death, followed by formation of antimicrobial metabolites, callose formation, lignification etc.(Kombrink *et al.*, 1995). In addition to the localized reaction, plants also respond with a defence system - called "systemic activated resistance" (SAR) - which is activated throughout the entire plant. It was shown that cucumber plants become resistant a few days after a localized infection, and that such local preinfection with e.g. tobacco mosaic virus protected the plants against at least 13 different diseases caused by bacteria, fungi and viruses (Madamanchi & Kuc, 1991). Biochemical studies on tobacco, cucumber and other dicots showed that SAR responses correlate with the accumulation of certain "pathogenicity related" (PR) proteins. Some of the PR proteins have been characterized as β-1,3-glucanases and chitinases which very likely play a certain role in SAR (Kessmann *et al.*, 1994). Salicylic acid is involved in the transduction of the systemic signal and plays a central role in the biological induction of SAR. To demonstrate that CGA 245704 indeed imitates the natural biological phenomenon of SAR, several studies have been carried out which led to following conclusions:

- neither CGA 245704 nor its metabolites have direct activity against target pathogens.
- it protects the plant against the same spectrum of pathogens as a biological activation (Kessmann *et al.*, 1996a).
- it is inactive in plants with a defective SAR signalling pathway. Studies with such plants strongly indicate, that both biological and chemical activators use the same signal chain leading to SAR (Lawton *et al.*, 1996).
- it causes the same biochemical changes in plants as a biological activation (Friedrich *et al.*, 1996).
- it requires a lag time between application and the build up of defence response.

In conclusion, all data indicate that CGA 245704 interferes with the same signalling pathway as used by biological activators. CGA 245704 acts as a funtional analogue of the natural signal molecule salicylic acid (Kessmann *et al.*, 1996b).

Interaction: product - host plant - pathogen

CGA 245704 is rapidly taken up and translocated throughout the entire plant. The induced defence reaction of the plant interferes at several sites with the pathogen life cycle. Studies with *Erysiphe graminis* f. sp. *tritici* in wheat showed a clear effect on fungal penetration rate as well as on formation of primary and secondary haustoria. Spore germination rate and appressoria formation were not altered (Görlach *et al.*, 1996).
The infection cycle of *Peronospora hyoscyami* f. sp. *tabacina* on tobacco was also affected at multiple sites. Germination and appressorium formation rate were not influenced by CGA 245704 but approximately 40% of these infection structures looked extremely swollen and did not differentiate further. The epidermal penetration on plants treated with CGA 245704 was only 50% as compared to untreated plants. After penetration, *P.hyoscyami* f.sp. *tabacina* forms a vesicle in the epidermis from which hyphal growth into the host tissue starts. In addition to its effect on the surface infection structures and penetration, the formation of these vesicles was reduced to approximately 50% compared to untreated plants. CGA 245704 treated plants showed intensive stain reactions around the areas of infection.

Field results on cereals

CGA 245704 is currently being developed for foliar spray applications on wheat and on spring barley. Representative data from European field trials demonstrate that a basic rate of 30g a.i./ha is sufficient to induce extraordinarily long-lasting suppression of foliar diseases on cereals.
The major benefit of CGA 245704 on cereals is the protection against *Erysiphe graminis*. CGA 245704 stimulates good protection against this pathogen, lasting up to ten weeks after a single treatment (Table 1). This effect is independent of the variety used. Other foliar pathogens (e.g. *Septoria* spp. and *Puccinia* spp. on wheat) are suppressed to a lesser extent (Table 3), but still leading to a retarded development of disease epidemics in general.
Because of its mode of action and the time interval required for the onset of SAR, optimal disease control with CGA 245704 alone is achieved with preventative applications between GS 25 and 29. This timing is also optimal with regard to crop tolerance. Applications later than GS 32 and treatments of stressed crops should be avoided, since cereal plants may respond with transient yellowing of lower leaves under such conditions.
Mixtures with fungicides are recommended for uses at GS 29-32, designed for situations where knock-down of existing or rapidly developing infections is required or to enlarge the spectrum of activity. Persistence of protection against powdery mildew is clearly improved by adding CGA 245704 to an early fungicide treatment (Table 2)

Table 1. Persistence of powdery mildew control on wheat, induced by CGA 245704, Western Europe 1994-95. (Applications at GS 30-31, 0-1 % mildew infection at spray application)

Treatments	Rate (g a.i./ha)	*E. graminis* on wheat Mean % infected leaf area / periods after application 1 - 3 weeks	 4 - 6 weeks	 7 - 10 weeks
Untreated	-	4	12	22
Fenpropidin	375	0	4	12
CGA 245704	30	2	2	9
Number of trials:		1	3	2

Table 2. Persistence of powdery mildew control induced by CGA 245704 in combination with knock-down activity provided by a fungicide on wheat, France, 1995.

Treatments	Rate (g a.i./ha)	*E. graminis* on wheat Mean % infected leaf area / periods after application 2 - 3 weeks	4 - 6 weeks	7 - 9 weeks
Untreated	-	25	21	35
Fenpropimorph + fenpropidin (3:1)	750	5	7	19
CGA 245704 + fenpropidin	30+375	7	3	8
Number of trials:		2	3	2

Applications at GS 31-32 / 4-13% 4-13 % leaf area affected at application

The mixture CGA 245704+cyprodinil is especially well suited for applications at GS 29-32. This combination provides eyespot control as well as long lasting suppression of powdery mildew. In addition, other diseases are also held back (Table 3), thus providing flexibility for the optimal placement of eventual follow-up treatments.
Depending on the degree of disease pressure, yield benefits up to +11% over untreated were obtained with a single application of 30g a.i./ha of CGA 245704 alone. Additional benefits of mixtures with fungicides are also reflected in yield results (Table 4).
In conclusion, an application of CGA 245704 made before GS 32 on cereals provides long lasting protection against powdery mildew.
If knock-down activity or a more broad spectrum control is needed, CGA 245704 can be used in mixtures or spray programmes with fungicides.

Table 3. Control of powdery mildew and eyespot and additional effects on foliar pathogens with the mixture CGA 245704+cyprodinil, Western Europe 1994-95.

Treatments	Rate (g a.i./ha)	Mean infection levels in % / pathosystems *Powdery mildew* *wheat*	*spring barley*	*Eyespot* *wheat*	*Leaf septoria* *wheat*	*Brown rust* *wheat*
Untreated	-	18	15	64	25	28
CGA 245704	30	6	6	-	19	20
CGA 245704	30+600	-	-	34	-	-
+ cyprodinil	30+500	3	-	-	16	17
	24+400	-	2	-	-	-
Number of trials:		18	3	4	13	4
Weeks after application:		3-10	3-4	8-10	5-10	6-10

Applications at GS 29-32

Table 4. Yield effects with CGA 245704 alone and in mixture with cyprodinil in Western Europe 1994.

	Treatments			
	Untreated	CGA 245704	CGA 245704+ cyprodinil	Propiconazole+ fenpropidin
Rate (g a.i./ha)		30	30+500	125+375 to 500
Yield (% relative to check)	100	109	117	115

Applications at GS 30-32. 7 trials, untreated yield 6.27 t/ha. *E. graminis, Septoria* spp., *P. recondita* present.

Field results in tobacco

CGA 245704 was tested during the last five years under European conditions for the protection of tobacco against blue mould, caused by *Peronospora hyoscyami* f. sp. *tabacina.* Results are presented from trials carried out in Italy and France. At moderate disease pressure, excellent protection was achieved with CGA 245704 at the low rate of 0.5-1.2 g a.i./hl and spray intervals of 7-8 days. With an extremely severe disease attack, a clear rate-activity response from 0.5 to 5.0 g a.i./hl was observed (Tablel 5). Because of certain crop tolerance problems on Burley tobacco, rates above 2.5 g a.i./hl were not further developed.
Table 6 shows the results of two French trials, comparing CGA 245704 alone and in mixture with metalaxyl or metalaxyl-M. CGA 245704 at 1.2 g a.i./hl applied at 14 day intervals provides moderate protection at high disease pressure. Under the same conditions, the mixture with metalaxyl or metalaxyl-M significantly improved the performance and provided almost complete control of blue mould. Table 7 shows the performance of the same mixtures in six trials in Italy. *P.hyoscyami* f. sp. *tabacina* was extremly well controlled by 3-5 applications in 8-10 day intervals, superior to the standard metalaxyl +mancozeb at much higher rates but at 14 day intervals.

Table 5. Impact of dose rate of CGA 245704 and disease pressure on protection of tobacco against *P.hyoscyami* f. sp. *tabacina.* (Average of 3 trials each with high and moderate disease pressure). Italy 1991-93.

Treatments	Rate g a.i./hl	Mean % infected leaf area			
		high disease pressure		moderate disease pressure	
		*33	54	33	54
Untreated		10.8	58.3	4.8	21
CGA 245704	0.5	5	30	0	0.1
CGA 245704	1.2	2.5	20	0	0
CGA 245704	5.0	1.2	7	-	-
Dimethomorph	20.0	1	8.3	-	-
Mancozeb	192.0	0.8	15.2	0	2.7

*evaluation in days after first application

Table 6. Performance of CGA 245704 alone and in mixture with metalaxyl or metalaxyl-M against *P.hyoscyami* f. sp. *tabacina*, France 1994-95.

Treatments	Rate g a.i./hl	Trial 1 (1994) Mean % infected leaf area (52 DALA)*	Trial 2 (1995) % infected plants (0 DALA)	No.of leaves attacked per plant (14 DALA)
Untreated		56.8	100	**(47.9)
CGA 245704	1.2	27.8	17.5	5.6
CGA 245704	2.5	21.2	-	-
CGA 245704+metalaxyl	1.2+24	0.1	0	0
CGA 245704+metalaxyl-M	1.2+12	-	0	0.1
Metalaxyl+maneb	40+80	0.3	0	0

Trial 2 with artificial inoculation.

*DALA= evaluation in days after last application

** in check: mean % infected leaf area

Table 7. Performance of CGA 245704 in mixture with metalaxyl or metalaxyl-M against *P.hyoscyami* f. sp. *tabacina*, 6 trials Italy 1992-95.

Treatment	Rate g a.i./hl	Spray interval days	Mean % leaf area affected 36-55 days after first spray
Untreated			27.2
CGA 245704+metalaxyl*, or	1.2+24	8-10	1.2
CGA 245704+metalaxyl-M**	1.2+12		
Metalaxyl+mancozeb	24+192	14	7.4

(*4 trials /** 2 trials)

Although CGA 245704 itself performes already quite well in many cases, the mixtures of CGA 245704+metalaxyl at 1.2+24 g a.i./hl or CGA 245704+metalaxyl-M at 1.2+12 g a.i./hl respectively at extremly low use rates provide a clearly better and more reliable protection of tobacco against blue mould. This mixtures are also well tolerated at recommended rates on all tobacco varieties tested so far.

SUMMARY AND CONCLUSION

The plant activator CGA 245704 belongs to a new category of compounds which have no direct activity against the pathogens but activate the plant's own defense mechanisms, leading to protection against diseases caused by fungi and bacteria. It imitates the natural, biological phenomenon of SAR. CGA 245704 has no toxic effect against fungi and bacteria and works only through the plant. In cereals, a long lasting protection against *E. graminis* and a suppressive effect on other diseases is achieved. It effectively protects tobacco against blue mould with very low use rates. Due to its particular modes of action, the development of resistance in pathogens seems to be very unlikely. CGA 245704 offers a new, innovative way in plant protection in addition to fungicides. It is not only a new chemistry but also a new technology.

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SESSION 2B

RECENT DEVELOPMENTS IN THE STUDY OF WHITEFLIES

Chairman	Mr C Furk *Pesticides Safety Directorate, York*
Session Organiser	Mr R A Umpelby *ADAS Rosemaund, Hereford*
Papers	2B-1 to 2B-4

BEMISIA TABACI: POTENTIAL INFESTATION AND VIRUS TRANSMISSION WITHIN THE ORNAMENTAL PLANT INDUSTRY

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ABSTRACT

The tobacco whitefly, *Bemisia tabaci*, is a statutory pest in the UK where it is associated with the importation of ornamental plants. Little is known about the suitability of the wide range of plants grown by the ornamentals industry as hosts for *B. tabaci*. This whitefly is differentially attracted to various plants but the B-biotype can adapt quickly to plant types which initially appear as relatively unsuitable hosts. No transmission of tomato yellow leaf curl virus was observed to five ornamental species tested with viruliferous whitefly. With its broad host range and adaptability to new host plants there is an increased risk of accidental introductions on a wider selection of plants and at different seasons than experienced previously.

INTRODUCTION

The tobacco, cotton, or sweetpotato whitefly, *Bemisia tabaci*, has always been a pest of a wide range of agricultural crops worldwide, sporadically causing damage by feeding and virus transmission (Markham *et al.*, 1994). However, since the early 1980s infestations of *B. tabaci* have increased in severity and importance (De Barro, 1995). The "B" type of *B. tabaci*, which is one of the 12 reported biotypes (Brown *et al.*, 1995), has spread widely through the international trade in ornamental crops (De Barro, 1995). It has an increased fecundity (Bethke *et al.*, 1991), a greater resistance to pesticides (Byrne & Devonshire, 1993), a wider range of host plants and a more aggressive feeding habit (De Barro, 1995). The B-biotype is recognised by a distinctive phytotoxic response known as squash silverleaf (Bedford *et al.*, 1994a) and by a characteristic esterase banding pattern (Costa & Brown, 1991; Byrne *et al.*, 1995). The name *B. argentifolii* (Bellows *et al.*, 1994), with the common name of silverleaf whitefly (Perring *et al.*, 1993), has been applied to the B-biotype but this is a controversial distinction which is not accepted widely (De Barro, 1995).

Britain has a protected zone status within the EU and, as a statutory pest, any suspected occurrence of *B. tabaci* must be reported to MAFF-PHSI (Anon, 1993). In southern Europe, the B-biotype has appeared in the field and it has become established in areas of the northern european glasshouse industry (Bedford *et al.*, 1994c). Previous work has shown that it will colonise most agricultural crop types, produce phytotoxic responses in some cultivars and transmit geminiviruses to particular crop varieties (Bedford *et al.*, 1992, 1993 & 1994a,b,c). The spread of the B-biotype brings an increased risk of novel virus infections to many plant types. Some of the wide range of plant species grown by the ornamentals industry are commonly imported into Britain as young plants for growing on, or for further propagation and distribution. Many of these are known to be good host plants for whitefly and it is likely that the B-biotype of *B. tabaci* could utilise many others. The only whitefly-transmitted geminivirus (WTG) known currently in Europe is in tomato and at present it is being called tomato yellow leaf curl virus (TYLCV) (Bedford *et al.*, 1994c). For this study we have tested a range of ornamental plants for susceptibility to whitefly infestation, infection with TYLCV from Almeria in Spain and for plant preference with two colonies of the B-biotype.

MATERIALS AND METHODS

Origin and maintenance of insects

B. tabaci were obtained either from a glasshouse infestation on *Solanum nigrum* in Florida, USA in 1991 (*B. tabaci*-FN) or from *Gossipium hirsutum* in the Yemen in 1989 (*B. tabaci*-YC). The Florida culture was kept at Norwich on *S. nigrum* plants at 25°C and 16h daylength. The Yemen culture was kept at HRI Wellesbourne at 26°C and 18h daylength.

Insect survival, adaptation to host crops and colony persistence

A range of plants were obtained from commercial outlets in the UK. Five hundred adult whitefly (*B. tabaci*-FN) were caged with two plants at 25°C and a 16h daylength. Plants were grown on for 7 weeks. An assessment of adult whitefly survival, oviposition, presence of nymphal stages and colony persistence was made 14 and 44 days after introduction.

Virus transmission

TYLCV-AL was collected from infected tomato plants in Almeria (Spain) during 1995 and maintained at Norwich by grafting infected scions onto healthy tomato plants. Whitefly from the *B. tabaci*-FN colony were given a 48h acquisition access period on infected plants. Individual seedlings of test plants were caged with 15 viruliferous adult *B. tabaci* in ventilated 150ml sterilin jars. The caged whitefly were left for six days to ensure adequate feeding and virus transmission. After this period any remaining whiteflies were removed, the plants were fumigated with the insecticide propoxur and then transferred to an insect proof glasshouse for observation of the development of virus symptoms. A dot blot hybridisation (Maule *et al.*, 1983), using DNA probes to TYLCV-AL, was done on each plant using leaves which were harvested 20 days after the fumigation treatment.

Plant preference

The two colonies of *B. tabaci* were tested for preference at Wellesbourne on the following ornamental plant types: *Fuchsia* "La Campanella"; *Lysimachia* "Aurea"; *Petunia* "Surfinia"; *Scaevola aemula*; *Verbena* "Blue" and *Viola* "Universal". The *B. tabaci*-FN colony, which had been reared for several generations on *Fuchsia*, was tested with eight replicates of six plant types and the *B. tabaci*-YC was tested with four replicates of the same six plant types. Each test was done in a containment growth room at 26°C and 18h daylength. The test plants were arranged on a rotating platform in four replicated groups of six plants. The plants in each group were organised into an equilateral triangle of one, two and three plants from the centre of the platform. The four groups combined to give a total of 24 plants which were arranged in three concentric rings of four, eight and twelve plants on each platform. The effect of plant position on preference was minimized by fully randomising the plant positions and by rotating the platform (Ellis & Hardman, 1975). A group of 250 *B. tabaci*-FN was released into each of two platforms and a group of 200 *B. tabaci*-YC was released into one platform. The number of *B. tabaci* on each plant was counted after 24h and 48h.

RESULTS

Insect survival, adaptation to host crops and colony persistence

The way in which *B. tabaci* adapted to the range of ornamental plants is summarised in Table 1. *B. tabaci* responded in different ways to the range of test plants. At one extreme is *Dianthus* where, although eggs and (misshapen) crawlers were present, no adults were found at the first assessment and the colony did not persist to the second assessment. At the other extreme *B. tabaci* developed a population which finally led to the destruction of the *Viola* plants. *B. tabaci* responded slowly to *Fuchsia* resulting in an extended generation time with the emergence of the first generation of adults after 44-59 days. The culture went on to produce a vigorous colony on *Fuchsia*. The remaining plant types showed an intermediate level of infestation. No specific phytotoxic responses were observed on any of the plants.

Table 1. Survival of *B. tabaci* on selected ornamental crop plants (- = none, * = presence at low numbers, ** = abundant ,*** = very abundant; 1 = misshaped or unhealthy larvae).

1st Assessment:	Adult survival	Presence of eggs	Presence of crawlers	Presence of sessile instars
Fuchsia "Beacon"	*	*	-	-
Dianthus "Princess"	-	*	*[1]	-
Petunia "Surfina"	**	**	*	*[1]
Ranunculus "Golden Queen"	*	***	***	***
Scaevola aemula	*	***	***	***
Viola "Yellow Princess"	**	**	**	-
2nd Assessment:				
Fuchsia "Beacon"	infestation persisting but adult emergence delayed to 44-59 days			
Dianthus "Princess"	no whitefly present.			
Petunia "Surfina"	infestation persisting with all life stages.			
Ranunculus "Golden Queen"	infestation persisting with all life stages.			
Scaevola aemula	infestation persisting with all life stages.			
Viola "Yellow Princess"	high infestation maintained leading to plant death.			

Virus transmission

Five plant species were tested for susceptibility to TYLCV-AL: *Calceolaria* "Melody"; *Cineraria* "Cindy"; *Abutilon* "Maximum"; *Dianthus* "Princess" and *Verbena* "Garden Party".

None showed susceptibility to TYLC-AL and no virus was detected by dot blot hybridisation.

Plant preference

The number of adult whitefly on each test plant was recorded after 24h and 48h. The proportion of adults found on each plant type was calculated from the overall number of whiteflies recovered and the mean values are given as percentages in Table 2. In assessment one a total of 281 (56.2%) of the 500 introduced *B. tabaci*-FN were recovered from the 48 test plants and only 15 (7.5%) of the 250 introduced *B. tabaci*-YC were recovered from the 24 test plants. In assessment two a total of 262 (52.4%) *B. tabaci*-FN were counted but only 8 (4%) *B. tabaci*-YC were counted. One third of the *B. tabaci*-FN recovered were found on *Viola* and a second third on *Lysimachia*. Although the *B. tabaci*-FN had been reared on *Fuchsia* only 10% were recovered from *Fuchsia*. Similar levels were found on both *Petunia* and *Verbena*. The lowest occurrence was recorded from *Scaevola*. A high mortality of the *B. tabaci*-YC occurred with only a low recovery of adult whitefly on the test plants which indicates that the *B. tabaci*-YC did not adapt well to the range of ornamental plants offered. Due to the very low recovery level and consequent variability in the results any preference patterns are not as evident with this colony as for *B. tabaci*-FN.

Table 2. The percentage of adult whiteflies recovered after 24h and 48h on the test plants.

	B. tabaci-FN				*B. tabaci*-YC			
Plant types	24h		48h		24h		48h	
	mean	SE	mean	SE	mean	SE	mean	SE
Fuchsia	11.2	± 2.8%	13.2	± 2.8%	26.7	± 26.7%	37.5	± 37.5%
Lysimachia	29.8	± 7.3%	21.2	± 4.8%	14.0	± 8.1%	12.5	± 12.5%
Petunia	10.1	± 3.3%	16.4	± 4.8%	27.0	± 15.4%	25.0	± 14.4%
Scaevola aemula	3.9	± 1.3%	2.	6±0.8%	0		0	
Verbena	11.6	± 7.7%	13.6	± 2.8%	14.0	± 8.1%	0	
Viola	33.4	± 5.8%	37.6	± 6.8%	20.0	± 20.0%	25.0	± 25.0%

DISCUSSION

B. tabaci is not indigenous to the UK and recent occurences have originated with the transport of ornamental plants (Cheek & Macdonald, 1993). The majority of infested imports have been associated with poinsettia, where young rooted cuttings are imported for growing on to produce finished plants in November and December. The eradication and management of these infestations has been facilitated by the late season because *B. tabaci* has a poor tolerance of low temperatures. However, with the firm establishment of the B-biotype in Europe there is a greater risk of importation on a wider range of crops and at different seasons. A list of plant hosts of *B. tabaci* which covers 80 genera in 34 families of ornamentals alone, out of a known host range of over 500 species in 74 plant families, is given in De Barro (1995). The small selection of ornamental plants examined here includes three families, Onagraceae (*Fuchsia*), Goodeniaceae (*Scaevola*) and Primulaceae (*Lysimachia*) which are not listed by De Barro (1995). Many more potentially good hosts for *B. tabaci* exist within the extensive range of plants grown by the ornamentals industry in the UK. A recent grower guide (Eames & Potter, 1995) lists over 100 different plant genera which are commonly available and includes many that are vegetatively propagated and imported annually as young plants.

We have shown that *B. tabaci* responds differently to different ornamental host plants. Different preference patterns were exhibited by *B. tabaci* but even plants with low preference are capable of supporting significant populations of the whitefly. Good host plants, like *Viola*, are attractive to *B. tabaci* and large populations develop rapidly on this host. Other plants, such as *Fuchsia*, are less attractive and *B. tabaci* develops initially more slowly but the progeny go on to develop strong populations on this host plant. However, the *Fuchsia*-adapted whitefly did not show a preference for this host plant in a preference test. The adults of the Florida strain survived well and took readily to the ornamental plants offered in the preference test. The adults of the Yemen strain did not survive well and no distinct preference was evident. Whether this reflects a biological difference that correlates with the distinction of two variants of the B-biotype, B and B_2, is unknown. *B. tabaci* from the Yemen have previously been characterised as B_2-biotype because they show an additional distinct esterase band to that of B-biotype elsewhere (Bedford *et al.,* 1992; 1994a). Alternatively the difference may reflect a selection for a more adaptable line through the use of survivors from a relatively unsuitable host such as *Fuchsia*. This aspect needs clarification as the implications are important to the ornamental plant industry.

One of the principal threats that *B. tabaci* posses is through the transmission of plant viruses. Most of the geminiviruses which are transmitted by *B. tabaci* originate from areas outside Europe but when tested some of these will infect certain agricultural crops (Bedford *et al.,* 1994c). We were unable to detect infection of the ornamental plants tested with TYLCV transmitted by the B-biotype of *B.tabaci*. However, there are other WTGs which infect tomato and produce leaf curl symptoms (Bedford *et al.,* 1994c) and possibly other geminiviruses in Europe. How these viruses may effect the wide range of ornamental plants and how the geminiviruses which result in aesthetically desired variegation in many ornamental plants interact with the B-biotype is an important consideration for the future.

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THE IDENTITIES OF LADYBIRD BEETLE PREDATORS USED FOR WHITEFLY CONTROL, WITH NOTE ON SOME WHITEFLY PARASITOIDES, IN EUROPE

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ABSTRACT

Three species of ladybird beetles are being used for the control of whiteflies in Europe. *Clitostethus arcuatus* is native to Europe, easy to identify and well known. The other two species were both poorly known taxonomically until recent work revealed their true identities. These two species, one originally from the New World, the other from northern India, are characterized and their previous use in biological control discussed. Five *Encarsia* species have recently been identified from economically important whiteflies in Europe. New distribution and host records are presented for these species.

INTRODUCTION

In Europe, there is a single native ladybird species, *Clitostethus arcuatus* (Coleoptera: Coccinellidae), which is a specialist predator of whiteflies (Homoptera: Aleyrodidae). Specimens of other coccinellids received by the International Institute of Entomology for identification have shown that two introduced species of Coccinellidae are being used in Europe as whitefly predators. Establishing the correct names for these species forms a major part of this paper. Hymenoptera specimens also received have provided new data on the distribution and hosts of several *Encarsia* species (Hymenoptera: Aphelinidae), whitefly parasitoids of economic importance.

LADYBIRD BEETLE PREDATORS

Clitostethus arcuatus

This species is native to the warmer parts of the western Palaearctic, particularly the northern Mediterranean. It occurs as a rarity in southern England, but does not extend as far north as Scandinavia or the Baltics. It has been introduced into Mauritius, Réunion, Bermuda and, very recently, California (Bellows *et al.*, 1992).

It is readily identifiable by its small size, c. 1.2-1.6 mm long, pubescent upper surface, and characteristic colour pattern forming a pale, inverted, horseshoe shape on the elytra. Although somewhat variable in its colour patterning, as illustrated by Gourreau (1974), there is usually little doubt about its identity. It keys out readily in Pope (1953).

A brief review of the hosts of *C. arcuatus* in Europe was provided by Bellows *et al.* (1992). They noted that it was a polyphagous species, feeding especially on the eggs and nymphs and sometimes on the adults of *Siphoninus phillyreae*, *S. immaculata*, *Aleyrodes proletella*, *Dialeurodes citri*, *Trialeurodes vaporariorum* and *Aleurothrixus floccosus*. Additional whitefly hosts include *Stenaleyrodes vinsoni* on Réunion (Russell & Etienne, 1985), *Trialeurodes ricini* (as *T. lubia*) in Iraq (Anon., 1977) and *Metaleurodicus cardini* on Bermuda (label data on specimens in The Natural History Museum, London). Other Homoptera and a single plant mite species have occasionally been recorded as prey.

Delphastus catalinae

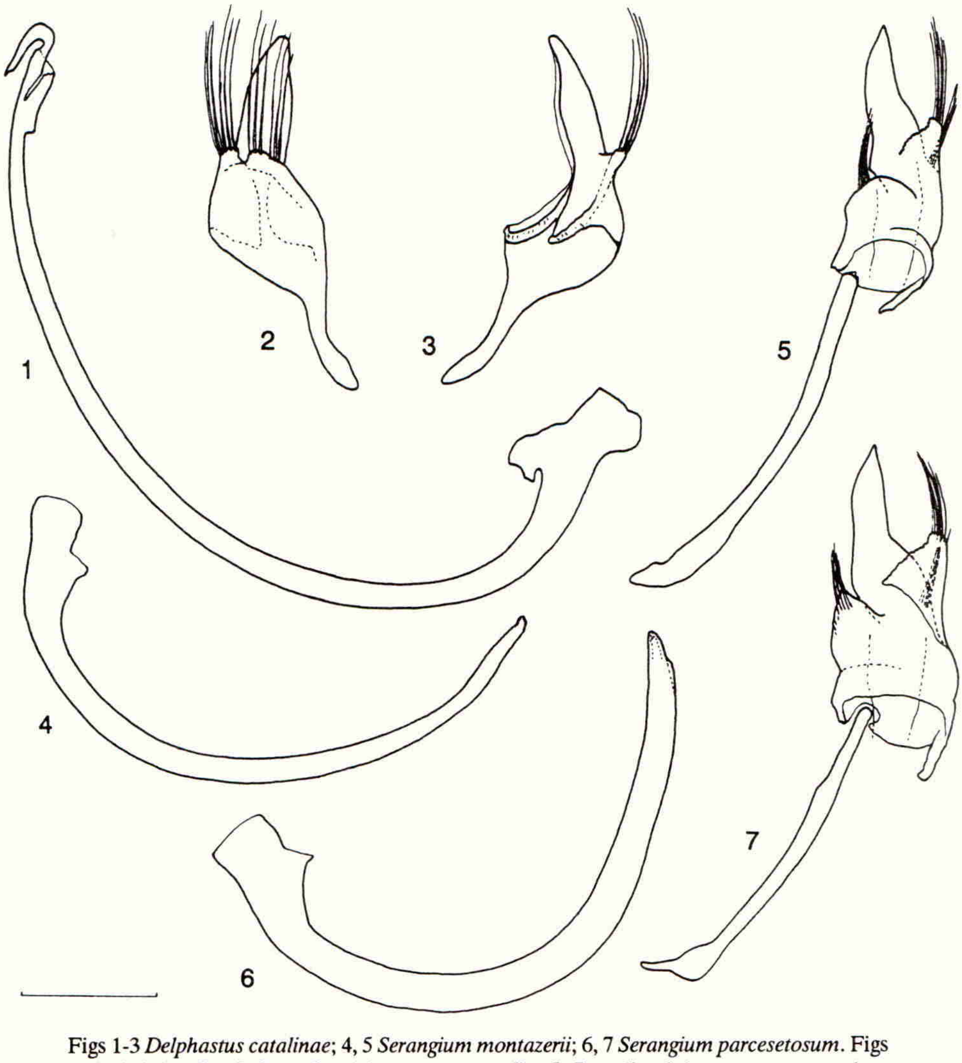
Cryptognatha catalinae Horn, 1895: 83.
Delphastus catalinae: Gordon, 1985: 63; 1994: 100.
Delphastus occidentalis Juarez & Zaragoza, 1990: 298; Gordon, 1994: 118; new synonymy.

The genus *Delphastus* is native to the New World and *D. catalinae* was recorded here by Gordon (1994) from California, Mexico, Colombia and Trinidad. Gordon (1994) also recorded it from Hawaii, where it was introduced for biological control from Trinidad, and from Tenerife, Canary Islands. Canary Islands specimens, received for identification in 1987 and 1988 from citrus or in glasshouses, were presumably deliberate introductions. In addition, the species has been introduced to Viti Levu, Fiji, presumably from Hawaii (specimens collected in 1986 and 1988). In 1995 and 1996, additional laboratory material of this species was examined from Israel, from the Netherlands (cutures from Israel), and from the UK (cutlures from a Canadian supplier).

A similar North American species, *D. pusillus*, has been reported as being released into greenhouses in the Netherlands (Fransen, 1994, and into avocado and citrus groves and greenhouses in Israel (Halperin *et al.*, 1995). Some of these releases probably refer to *D. catalinae* and not to *D. pusillus*. Halperin *et al.* (1995) listed Florida and Hawaii as the source of Israeli material; the Hawaiian material would have been *D. catalinae*, whereas the Florida material, if field collected, could well have been the native *D. pusillus*. The Netherlands greenhouse material may also be *D. catalinae*, since this latter species is being cultured by a Dutch biological control laboratory.

Delphastus catalinae belongs to the tribe Serangiini which is not represented by any native European species. It will therefore not key out in any European texts, but may be keyed out from North American work (Gordon, 1985), and separated from similar species using the generic revision by Gordon (1994). It is small, c. 1.3-1.7 mm long, broadly oval, strongly convex above and moderately convex below, brown to pitchy in colour, with paler legs. The head is paler brown in males, darker in females. The head, pronotum and base of elytra bear a few scattered, elongate, erect setae, but otherwise, the elytra are glabrous. The antennae are 9-segmented, with the apical segment much enlarged and elongated, about twice as long as broad, thus forming a 1-segmented club which is one characteristic of the tribe Serangiini. In addition, the prosternum is produced forwards into a curving arch, concealing the mouthparts when the head is in repose. *D. catalinae* is similar to *D. pusillus*, a native of eastern North America (Gordon, 1994). They may be separated externally by the punctation of the prosternum which is dense and relatively coarse in *D. catalinae*, but very fine and widely scattered in *D. pusillus*. The male genitalia (figs 1-3) will readily separate *D. catalinae* from all other *Delphastus* species. The parameres (figs 2, 3) are very short, yet distinct, and bear long setae, reaching the apex of the median lobe. The sipho bears a very weakly sclerotized apex which is recurved (fig. 1) when freshly dissected, but which usually twists and collapses when the sipho is stored in glycerine. This explains the different shape illustrated by figure 1 compared with Gordon's (1985, 1994) figures for the same organ. Juarez & Zaragoza's (1990) figures for the sipho of their new species, *D. occidentalis*, described from Mexico, show the same character, but with the apex twisted through 180°. *D. occidentalis* is therefore sunk in synonymy with *D. catalinae* (new synonymy).

Gordon (1994) listed *Aleurothrixus floccosus*, *Pealius kelloggi*, *Dialeurodes citri* and *D. citrifolii* as hosts. Specimens from Fiji were preying on *Aleurodicus dispersus*. Laboratory cultures from Israel were maintained on *Dialeurodes citri*, those from the UK on *Trialeurodes vaporariorum*. If Fransen's (1994) reference to *D. pusillus* actually refers to *D. catalinae*, then *Bemisia tabaci* can also be added to the above list.



Figs 1-3 *Delphastus catalinae*; 4, 5 *Serangium montazerii*; 6, 7 *Serangium parcesetosum*. Figs 1, 4, 6 sipho; figs 2, 3 median lobe, parameres; figs 5, 7 median lobe, parameres, trabes. (scale marker = 125 µm, figs 1-3; 250 µm, figs 4-7)

Serangium montazerii

Serangium montazerii Fürsch, 1995: 20
Serangium parcesetosum: Timofeyeva & Hoang, 1978: 302 [misidentification]

The genus *Serangium* contains species native to Africa, the Oriental region and Australia. *S. montazerii* appears to be native to northern India and Pakistan; specimens have been seen from Rawalpindi, Pakistan and Timofeyeva & Hoang (1978) recorded it from Ranikhet, Uttar Pradesh, India. Specimens from Ranikhet were released into Adzharia in the Black Sea coastal region of Georgia. Since then, the species has been deliberately introduced for the biological control of whiteflies into France and Corsica, introduced from Georgia (Malausa *et al.*, 1988), and into Israel, introduced from France (Halperin *et al.*, 1995). It has also recently been found in Iran (Fürsch, 1995) and Syria (specimens received in 1995).

Serangium montazerii is structurally similar to *Delphastus catalinae*; they are members of the same tribe of ladybirds. *S. montazerii* is larger, c. 1.9-2.3 mm long, almost circular in outline, strongly convex above, but only weakly convex below, and uniformly orangey-brown in colour. *S. montazerii* is very closely similar to *S. parcesetosum*, described from southern India. Although the former has fine elytral punctation which is a little more noticeable than that of *S. parcesetosum*, and slightly smaller, more widely separated eyes, the male genitalia provide the best means of species separation. A male paratype of *S. montazerii* was examined and its genitalia studied (figs 4, 5) because Fürsch's (1995) figure, in lateral view, of the genitalia of his new species cannot be used to separate the above two species. There is no doubt that this is the same species as that figured by Timofeyeva & Hoang (1978). The lower paramere (on the left side of figure 5) is very broadly rounded in *S. montazerii*, while it is triangular in *S. parcesetosum* (fig. 7). The median lobe also differs and the sipho in *S. montazerii* (fig. 4) is more slender than that of *S. parcesetosum* (fig. 6). Sicard (1929) described *Serangium parcesetosum* from an unrecorded number of specimens from Coimbatore, southern India. The single syntype in The Natural History Museum, a female labelled "S. India Coimbatore, grubs feeding on castor Aleurodes, 20.iv.28, T.K.V.Coll./ Serangium parcesetosum Sic types [Sicard's handwriting]", is here designated as the lectotype of *Serangium parcesetosum*.

The citrus whitefly, *Dialeurodes citri*, was the target host for *S. montazerii* in Georgia (Timofeyeva & Hoang, 1978), France and Corsica (Malausa *et al.*, 1988), and the same host species was used to maintain it in culture in Israel. Other host records from India refer to the true *S. parcesetosum*, not to *S. montazerii*.

HYMENOPTEROUS PARASITOIDS

Encarsia adrianae

This species, described from Pakistan by Lopez-Avila, is essentially Oriental (India, Pakistan, Japan) in distribution (Polaszek *et al.*, 1992). It is now also known from Europe (Italy, Spain) and the Near East (Jordan). Polaszek *et al.* (1992) commented on its possible synonymy with *E. azimi* and *E. reticulata*.
Material examined: 1♀ ITALY, Calabria, 6 Km E. of Pizzo, 19.viii.88 (J S Noyes); 1♀

SPAIN, Andalucia, 15.xi.94 (J E G Zamora) *ex Bemisia tabaci*-complex; 2♀ JORDAN, Darab, 2.xi.92 (H Alemansoor) *ex Bemisia tabaci*-complex.

Encarsia hispida

This normally biparental Neotropical species was known from Europe (Spain, Italy) from uniparental populations (Polaszek *et al.*, 1992). It is now known to occur additionally in France and Portugal (Madeira).
Material examined: 2♀ FRANCE, Antibes, 11.iii.94 (J-C Onillon) *ex Trialeurodes vaporariorum* on *Ageratum* sp.; 1♀ MADEIRA, Lombo da Boa Vista, Funchal, 9.iv.95 175m (F Aguiar) P263 *ex Lipaleyrodes* sp. on *Chlorophytum comosum*; 1♀ MADEIRA, Funchal, 8.vii.93 60m (F Aguiar) P130 *ex Aleurotrachelus rhamnicola* on *Passiflora edulis*.

Encarsia mineoi

Previously recorded from Egypt, Sudan (Polaszek *et al.*, 1992) and Libya (Viggiani, 1982), this species is recorded here for the first time from Europe (Spain).
Material examined: 2♂ SPAIN, Almeria, Nijar, 26.xi.93 (J E G Zamora) *ex B. tabaci* on sweet pepper; 2♀ SPAIN, Almeria, Nijar, 17.v.95 (J E G Zamora) *ex B. tabaci* on melon.

Encarsia strenua

E. strenua is widespread and pantropical (Polaszek *et al.*, 1992), but, until recently, it was not known from Europe. In 1994 specimens from Spain were received and a further Spanish sample was identified as *E. strenua* by Mrs Antonia Soto Sanchez of Valencia.
Material examined: 4♀ SPAIN, Valencia, 9.v.94 (F Ferragut) IIE 23098 *ex Parabemisia myricae*.

Encarsia transvena

This is an extremely widespread species, and it is hardly surprising that it now appears to be invading Europe, although it was only recorded here recently from Italy (Viggiani, 1994). It is now known additionally from mainland Spain and the Canary Islands.
Material examined: 1♀ SPAIN, Malaga, 1991 IIE 22003 *ex P. myricae* on lemon; 1♀ ISLAS CANARIAS, Tenerife, Aqua Dulce, 5.xii.94 *ex Bemisia tabaci* on *Hibiscus*.

In addition to these new records for Europe, specimens of *Encarsia armata*, another Oriental species, have been identified recently from Jordan and Turkey, in both cases from *Dialeurodes citri*. Its future occurrence in Europe is predicted. In conclusion, it appears that the invasion of Europe by Oriental aleyrodids such as *D. citri* and *P. myricae* is being closely followed by that of their natural enemies.

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INSECTICIDE RESISTANCE IN *BEMISIA TABACI* - CURRENT STATUS AND IMPLICATIONS FOR MANAGEMENT

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ABSTRACT

Resistance in *Bemisia tabaci* to organophosphates (OPs) , carbamates, pyrethroids and endosulfan is widespread and the use of previously synergistic OP/pyrethroid mixtures appears to be selecting for new or modified resistance mechanisms. Resistance to the newest and most promising whitefly insecticides such as buprofezin, pyriproxyfen and imidacloprid has already been detected in localised areas. Considering the extent to which whiteflies are transported between countries the implications for countries and cropping-systems that receive these invaders are critical.

INTRODUCTION

Bemisia tabaci Gennadius (Homoptera: Aleyrodidae) is an extremely invasive, widespread and adaptable pest. It is found in almost all major agricultural systems, from cotton and vegetable field crops in the south-western American desert to ornamentals and vegetables in Temperate and Mediterranean Europe. The recent geographical expansion has been due in part to a *Bemisia* biotype initially associated with poinsettia production and transported via the ornamental trade to regions where it established and flourished, as well as changes in agronomy, over-use of insecticides and loss of natural enemies. Biological, behavioural and genomic characters of this biotype were compared to the endemic American *Bemisia* species (A-type) and the invasive biotype (also known as the B-type) subsequently renamed *Bemisia argentifolii* (Bellows *et al.*, 1994) . Similar analyses of *Bemisia* populations from other regions suggest that at least five biotypes or species could be identified, although the evolutionary and practical significance as well as the systematics of these biotypes is yet to be elucidated.

Bemisia tabaci has demonstrated an outstanding propensity for rapidly evolving resistance to insecticides which further compounds the already difficult task of controlling this pest. This paper reviews the current status of insecticide resistance in *B. tabaci* and discusses management and control implications.

CURRENT RESISTANCE STATUS

OPs and carbamates

B. tabaci resistance to OPs and carbamates was documented first in the early 1980s and since then it has been detected from all the areas where it is a pest (Table 1). The pattern of cross-resistance between OPs has not always been clear. Dittrich *et al.* (1990) reported lower levels of profenofos and chlorfenvinphos resistance compared to e.g. monocrotophos, dimethoate and methamidophos in Turkish and Sudanese populations, while Prabhaker *et. al.* (1985) reported lower levels of chlorpyriphos and monocrotophos resistance compared to methyl-parathion and sulprofos. These differences probably reflect different resistance mechanisms, although all OP resistant populations recently characterised have had one of two target site (acetylcholinesterase) insensitive variants known to confer OP and carbamate resistance (Byrne *et al.*, 1994). The most common insensitive variant was first characterised for a

Sudanese strain and has since been found in B- and non-B-types from various regions. Metabolic resistance has also been implicated from a number of studies using synergists.

Table 1. Resistance in *Bemisia tabaci* from a number of regions to a range of insecticides.
A blank cell indicates no data; no R = no resistance detected; * = resistance detected; ** = moderate levels of resistance; *** = high resistance; **** = extreme resistance. OPs = organophosphates; CARB = carbamates; SPs = synthetic pyrethroids; END = endosulfan; BUP = buprofezin; IMID = imidacloprid; OP/SP = OP/pyrethroid mixtures.

	SPs	OPs	CARB	END	BUP	IMID	OP/SP	Reference
Australia	**	**		**	*			1
Belize	**	**					*	2
Cyprus	**	**					*	2
Ethiopia		*						3
Guatemala	**	**						4
India		*			no R			1
Israel	**	**	**	**	*	no R	*	1,5
Japan		**	**	**	**			1
Mexico	**	*		***	*			1,8
Netherlands	****	***		**	***	no R		1,6,8
Nicaragua	**	***						4
Pakistan	***	***	**	**	no R	no R	**	1,7
Peru	*	*						3
Spain	***	***		***	**	**	**	1,6,8
Sudan	***	***	**	**			**	4
Turkey	*	**						4
UK	***	**	**		**		**	1,2,8
USA	****	****		***	*	no R	***	1,2,8,9,10

References; 1, (Cahill, unpub. data) ; 2, (Cahill *et al.*, 1995); 3, (Lemon, 1992) ; 4, (Dittrich *et al.*, 1990) ; 5, (Horowitz *et al.*, 1994) ; 6, (Cahill *et al.*, 1996b) ; 7, (Cahill *et al.*, 1994) ; 8, (Cahill *et al.*, 1996a) ; 9, (Dennehy *et al.*, 1995) ; 10, (Prabhaker *et al.*, 1992)

Pyrethroids

Pyrethroid resistance is also widespread (Table 1) although the levels of resistance and cross-resistance patterns vary considerably. A Belize strain tested in 1993 was moderately resistant to cypermethrin and etofenprox but not to bifenthrin, a result similar to that reported by Dittrich *et. al.* (1990) for Sudanese populations. By contrast, recent strains from Pakistan show extreme levels of bifenthrin and etofenprox resistance as well as considerable resistance to the older pyrethroids. Recent data from Arizona and California using either fenpropathrin bifenthrin or cypermethrin (Dennehy *et al.*, 1995; Prabhaker *et al.*, 1992) again demonstrate how resistance to pyrethroids has increased subsequent to their use, although variation in resistance frequencies and levels between regions in the south-west USA do occur and may be explained by localised selection and population dynamics. Although esterases are implicated in pyrethroid resistance, little detailed biochemical information is available. The possibility of target site insensitivity has yet to be fully explored.

Endosulfan

Endosulfan is the only organochlorine still widely used for *Bemisia* control although, as is common with the OPs and pyrethroids, it is often used as a tank-mix component. *Bemisia* resistance levels to endosulfan are generally reported to be low to moderate (Table 1) with LC_{50}s less than 30ppm except in one strain from the Sudan (Ahmed *et al.*, 1987) for which the LC_{50} was 400ppm. The uniformity of response is further supported by an apparently widespread homologous cyclodiene target-site modification identified by a polymerase-chain-reaction (PCR) based molecular diagnostic that confers endosulfan resistance to a range of insect species including all the biotypes of *Bemisia* so far studied (Anthony *et al*., 1995) .

Buprofezin

This insect growth regulator (IGR) is both extremely effective against the immature stages of whitefly and benign to natural enemies. It has been used in Europe since 1989 and the first significant resistance in *Bemisia* was reported for a strain collected in 1992 from a glasshouse in the Netherlands which had been treated with the product 22 times within 18 months. The combination of excessive use in the high resistance-risk environment of a glasshouse clearly contributed to the selection for resistance. A similar set of chemical use and ecological conditions in the intensive vegetable production system of southern Spain has also selected for a low frequency of buprofezin resistance in that area. The initial detection of buprofezin resistance in *Bemisia* populations collected from UK glasshouses was prior to its UK registration (Cahill *et al*., 1996b). These populations were all introductions from countries where buprofezin resistance had already been detected. Horowitz *et. al.* (1995) also monitored buprofezin resistance and reported low level resistance in *Bemisia* populations from Israeli greenhouses, again highlighting the high-risk conditions.

Imidacloprid

This is the first commercial example of a new class of insecticide with the potential to rival the OPs and pyrethroids. It is very effective against whiteflies and other sucking pests and in some regions where the older insecticides have become ineffective due to resistance has all but displaced them from the market. As for buprofezin, the combination of high resistance-risk conditions of greenhouse production and over-use of the product has selected for resistance in a localised area of southern Spain. Extensive monitoring programmes to detect the earliest hints of imidacloprid resistance are currently being developed in many countries and general resistance guidelines have been published (Elbert *et al*., 1996) . The apparent ease with which researchers in California were able to select for more than 40 fold resistance to imidacloprid in a field collected strain of *Bemisia* (Prabhaker *et al*., 1995) demonstrates that resistance genes to this product are already present in the field.

Pyriproxyfen

This juvenile hormone mimic has so far been extensively used only in Israel which is the source of the first report of resistance to this product. One of the outstanding features of this insecticide is its ovicidal activity. However, the resistance to pyriproxyfen was much more strongly expressed in terms of egg hatch (>500x) than on immatures (10x) (Horowitz & Ishaaya, 1994). These authors report no cross-resistance between pyriproxyfen and buprofezin and so far there is no information on the biochemical basis of resistance to either of these products.

Others

Other new insecticides about to be released for whitefly control include the carbodiimide derivative, diafenthiuron and the feeding arrestant, pymetrozine. These are structurally and functionally dissimilar from each other and any of the other insecticides above and no cases of resistance have yet been reported to these insecticides. Both products have posed considerable challenges for bioassay development due to either the requirement for photo-activation (diafenthiuron) or the extended time to final mortality (pymetrozine). Modifications to the standard adult leaf-dip bioassays were required and protocols approved by the manufacturers (Denholm *et al*., 1995).

Nicotine is still used in greenhouses for general pest control. Resistance to this botanical has been difficult to determine although significant differences exist between some glasshouse populations (M Cahill *et al.*, unpub. data). The same target site for nicotine and imidacloprid indicates the need to identify the resistance and cross-resistance patterns between these two insecticides.

Mixtures

The use of insecticide mixtures for *Bemisia* control is not new. Endosulfan mixed with OPs or pyrethroids gave better control of Sudanese populations than OPs or pyrethroids alone (Abdeldaffie *et al.*, 1987) and OP/pyrethroid combinations have been used in Pakistan, Israel, and the USA for some time. The biochemical basis of these combinations generally assumes that OPs inhibit the esterases responsible for pyrethroid resistance, although the most effective combinations have been selected by laboratory and field trials and not on the basis of biochemical reasoning. The combination of fenpropathrin and acephate widely used in Arizona and California was, initially at least, particularly effective, as very high resistance was present to both constituents but good control was achieved with the combination. Extensive use of this mixture for two years has, however, selected for additional resistance mechanism(s) that now confer resistance to the combination (Dennehy *et al.*, 1995).

Biotypes

The appearance of the B-type and simultaneous reports of insecticide resistance provoked some supposition of a link between these events. Studies at Rothamsted on a range of populations have shown that resistance is not confined to the B-type (some of the highest resistance levels were found in non-B-types from Pakistan). Nor is the B-type more uniformly resistant to insecticides, resistant to a wider range, generally more resistant to any one, or apparently pre-disposed to resist new insecticides. Studies on resistance mechanisms also show that the most common insensitive acetylcholinesterase variant conferring OP resistance is common to B and non-B-types and the mutation for endosulfan resistance is also identical between biotypes. The B-type's extreme polyphagy and occurrence in high value crops does, however, increase it's world-wide exposure to insecticides which may select for resistance to a wider range of insecticides.

MOVEMENT BETWEEN COUNTRIES

The international trade in *Bemisia* hosts (especially poinsettia) has implications for the movement of the insect and also the genes conferring resistance to a range of insecticides. This, coupled with the asynchronous nature of pesticide registration between countries, allows resistance to be selected for and transported to an area either before registration or in spite of the best intentions of the local manufacturers and industries.

Any solution to this problem will require that either quarantine authorities have the will and ability to prevent incursions of *Bemisia* populations or that sources of the immigrating pest are not under such severe insecticide selection pressures. These two aims may in fact be mutually exclusive, because to achieve zero quarantine tolerance often requires extreme control measures.

IMPLICATIONS FOR CONTROL AND OPTIONS FOR MANAGEMENT

The greatest chance that insecticides will remain a sustainable component of *Bemisia* management, lies with international implementation of resistance management tactics. Excluding the older 'conventional' insecticides which still have a niche in some areas, there are now available five new molecules with different modes of action. Even when, as in Israel, most of these were available simultaneously so that an integrated resistance management strategy could be implemented, cases of resistance to one of the newer insecticides soon emerged. Again it was in the greenhouse eco-system that resistance was selected, but this soon appeared in nearby cotton fields. This scenario of localised hot-spots with subsequent radiation of resistance, mirrors the international situation.

The use of synergistic mixtures to control *Bemisia* that resist either or both components has much to offer. This however, is not resistance management *per se*, as overuse of these combinations will certainly lead to additional resistance mechanisms and loss of control. Such mixtures are also vulnerable to resistance and should be used accordingly. A range of insecticide combinations are now used for control of the pest complex that includes whiteflies. These are often combinations of two insecticides from one manufacturer, and the rational for their partnership is primarily marketing or control of the pest complex rather than resistance management. The only experimental evidence that some combinations can delay the development of resistance in whiteflies comes from Prabhaker *et. al.*, (1994), although their preferred strategy was a three way rotation of single insecticides.

CONCLUSIONS

Insecticide resistance in Bemisia is geographically widespread and includes all the older as well as many of the newer insecticides. The worldwide movement of Bemisia hosts is disseminating novel resistance genes and may compromise the use of these insecticides in spite of the efforts of local industries.

Resistance management for greenhouses has been generally overlooked compared to field crops, which is surprising considering the scope for manipulating operational factors, for monitoring the biological components and the possibility of containing unwanted experimental results. Considering that these are the sources of the first reports of resistance to three of the five new molecules for *Bemisia* control it is apparent that this situation requires attention. A recent paper by Sanderson & Roush (1995) has begun to stimulate discussion and hopefully experimentation.

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OCCURRENCE OF B-BIOTYPE OF *BEMISIA TABACI* IN PAKISTAN

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ABSTRACT

The presence of B-type of *Bemisia tabaci* in Pakistan was established through biological (squash silverleaf-SSL symptoms) and biochemical (esterase banding patterns) studies. Distinct and definitive SSL symptoms were produced in squash (*Cucurbita pepo*) on which whiteflies obtained from cotton growing area of Multan, Pakistan were allowed to feed. Temperature had an effect on duration of symptoms development. Parent population yielded two types of esterase banding patterns, one with two densely stained bands and the other with only one major band. Whiteflies from SSL exhibiting plants produced only single band pattern. This is the first substantiated evidence for the presence of B-type of *B. tabaci* in Pakistan.

INTRODUCTION

Recently sweet potato whitefly, *Bemisia tabaci* has emerged as a serious pest of vegetable and fiber crops and it now posses a serious threat to the success of agriculture throughout the world (Brown, 1994). It has caused losses unmatched in the history of agricultural entomology. More than 500 plant species are listed as host of *B. tabaci*. It decreases the yield by draining out nutrients from the plant it feeds on, by production of large amount of sticky honeydew on which sooty mould grows later, and by serving as a vector of important plant viruses.

The sweet-potato whitefly was first described as a pest of tobacco in Greece (Gennadius, 1889) and was known to occur in most countries of the world, including Pakistan. Since the 1980s it has become more important in areas where it had been established but had not caused the losses of the magnitude experienced in recent years. Integrated crop management strategies and use of available pesticides failed to curb the infestations by *B. tabaci* in USA and other parts of the world. The recent increase in severity was attributed to the emergence of a new biotype of *B. tabaci*. This new biotype was referred to as B-type (Costa & Brown, 1991), or the poinsettia strain (Bethke *et al.*, 1991; Costa & Brown, 1991) and Silverleaf whitefly (Perring *et al.*, 1993). More recently Bellows *et al.*, (1994) presented additional evidence for considering B-type as a separate species and proposed the scientific name *Bemisia argentifolii*.

Pakistan stands among the leading cotton growing countries of the world with an annual production about 13 million bales (2.21 million metric tons). Pakistan's agriculture-based economy depends largely on production of cotton, which is the most important cash crop. In recent years a damaging virus disease, cotton leaf curl, first observed in a few plants in 1967, spread and caused considerable losses during 1987/88. From 1991/92 it became an epidemic form causing 50% yield reduction, with losses of upto 100%. Losses in individual cotton fields depended on variety, time of infection and environmental conditions.

The cause of the disease has been identified as cotton leaf curl virus (CLCuV), vectored by *B. tabaci*, (Hameed *et al.*, 1994). The factors leading to its epidemic are poorly understood. It is suggested that changes in agronomic practices, disruption of natural balance of beneficial insect fauna due to excessive use of pesticides, increased level of resistance in the insect against commonly used pesticides, and cultivation of susceptible and genetically more homogeneous varieties are the main causes. It is generally believed that the widespread planting of susceptible varieties played a major role in the eruption of CLCuV epidemic. Although all of the above mentioned factors would definitely have a role in CLCuV epidemic, the part played by changes in population structure of the vector may be more significant. This, however, is not taken seriously at present. The aim of this study was to ascertain whether some change has occurred in *B. tabaci* and to determine whether B-type is present in Pakistan.

MATERIALS AND METHODS

Whitefly Culture

Whiteflies used in this study were collected from commercial crops during 1994 cotton season from Multan. The insects were maintained and reared on cotton plants in rectangular perspex cages in a growth-room at 30-35°C under 14 hr daylength. Host plants were replaced periodically by new ones so that breeding activity was enhanced.

Biological Studies

A group of 10-15 adult whiteflies was released on seedling of *Cucurbita pepo* (cv. Aladdin) at 3-4 leaf stage. Cages were placed at two different temperatures i.e. 30-35°C and 20-22°C. Plants were observed daily for the appearance of squash silverleaf (SSL) symptoms.

Esterase analysis

Adult whiteflies were collected and immediately frozen at -20°C. Individual whiteflies were homogenized in 12 μl 0.1 M Tris-Borate-EDTA buffer, pH 7.0, containing 10 percent sucrose (Wool et al., 1989). Samples were analyzed by polyacrylamide gel electrophoresis (PAGE) using 7% gel in Tris-Glycine buffer system (pH 8.3). Gels were stained for esterase activity at room temperature in 0.2 M phosphate buffer, pH 6.5 using beta naphthyl butyrate as substrate and fast blue RR stain (Liu *et al.*, 1992, Costa & Brown, 1991).

RESULTS AND DISCUSSION

SSL symptoms were induced on all 32 plants of *C. pepo* as a result of feeding by whitefly culture used in this study. First symptoms of SSL were noticed after 8-9 days at 30-35^{0}C while at 20-22^{0}C the symptoms appeared after 20 days. Unexposed to whiteflies, the control plants did not show any SSL symptoms. The symptoms first appeared as clearing of veins on the new foliar growth. The severity of the symptoms progressed by silvering of leaf and subsequently whole leaf appeared silvery (Fig. 1).

Individual whitefly extracts yielded two distinct esterase banding patterns in PAGE. In all samples taken from the parent colony, one densely stained band migrated to the same location in gel (band 1). In some cases an additional clear band (band 2) was also visible just behind the band 1 (Fig. 2a). At times few minor bands were also present, but the signals were generally faint and appeared only after prolonged staining. This indicated that heterogeneity does exist among the population of whitefly prevalent in cotton growing area of Pakistan.

Having determined the different esterase banding pattern producing whiteflies were present, attempts were made to maintain separate populations of B-type which produced SSL symptoms separately. A group of five adults whiteflies was collected from single zucchini plant showing SSL, and released on fresh healthy zucchini for re-induction of these symptoms. In case symptoms developed, the procedure was repeated until a homogenous population was achieved which repeatedly yielded only band 1 (Fig. 2b).

DISCUSSION

Costa and Brown (1991) reported that A-type has at least two densely stained bands while B-type has only one major esterase band which migrates faster than both the bands of A-type. A major single esterase band in B-type whitefly is also reported by Perring *et al.*, (1992) using isoelectric focusing. In the present study, although a single band is found in SSL associated whiteflies (band 1), yet differs from that described by Costa and Brown (1991) as it moves to the same position in the gel as the faster band of A-type. At the same time we failed to find any whitefly with only band 2, the slower band of densely stained duplex of A-type. This indicates that the two bands (band 1&2) of A-type are not a result of polymorphism at the same locus.

Based on the data presented it is established that B-type of whitefly is present in Pakistan but it's role in CLCuV epidemic is yet to be determined. While increase in the frequency of whitefly peaks during cotton season has recently been observed on one hand (Shakeel, personal communication), on the other hand resistance to commonly used pesticides is also documented (Cahill *et al.*, 1994). Presence of B-type could be due to some genetic changes which could either be spontaneous, or brought about by selection pressure exerted by the ever increasing and indiscriminate use of pesticides, or might have been introduced with imported plant material. Such worldwide transport of B-type through ornamentals and vegetable transplants has been suggested by Brown (1994).

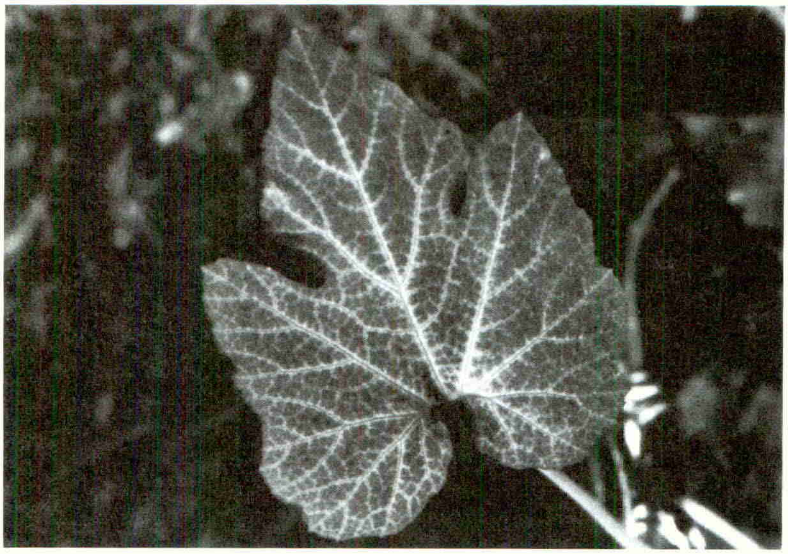

Figure 1. Squash silverleaf (SSL) symptoms induced by *B. tabaci* (B-type) on Cucurbeta pepo.

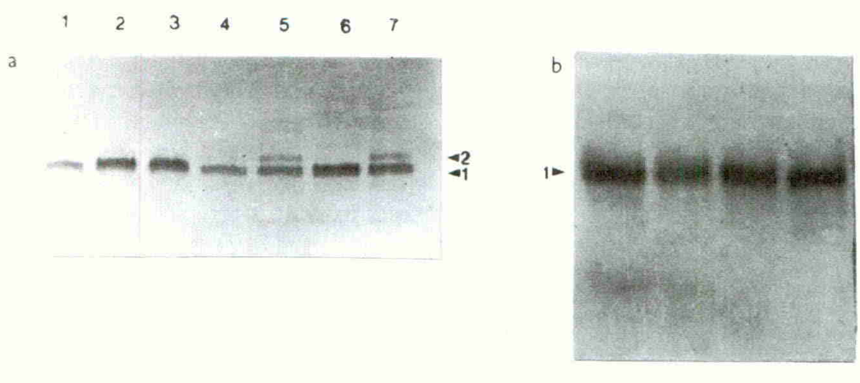

Figure 2. Electrophoretic profiles of estrases extracted from individual *B. tabaci* a) from field population maintained at the centre. Two distinct patterns with single major band (B-type) or two major bands (A-type) are clearly visible. Faster band (band 1) is common to all samples tested, while the slower band (band 2) is seen only in lane 6 and 7.
b) from SSL producing zucchini plant, showing only one band i.e. typical of B-type.

Since the presence of B-type in Pakistan has been demonstrated, a careful study is needed to ascertain the prevalence of B-type throughout the country. This is a prerequisite and critical step in search for any future management options in the IPM of cotton and other crops, as B-type is known to have biological characteristics different from A type. These include new pathogen transmission characteristics, broader host range, higher honeydew production, higher egg production and different esterase patterns (Byrne & Miller, 1990; Bethke *et al.*, 1991; Costa & Brown, 1991; Liu *et al.*, 1992; Perring *et al.*, 1992).

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