Sulphur: A SECONDARY NOT ANYMORE!

Steve McGrath

Sulphur deficiency was rare in European crops until about two decades ago. However, with the rapid decline in S deposition from the atmosphere due to controls on acid rain, the situation is changing rapidly. Today, sulphur has become one of the most limiting nutrients for agricultural production in many countries in Europe as it also has in the Indian Subcontinent and in South East Asia. In Australasia, sulphur has been known to limit crop production for a long time while in North America crop responses to sulphur application are increasingly reported. A recent conference on sulphur organized by the International Fertilizer Society (IFS) provides a very timely opportunity for New Ag International to cover a number of aspects on a formerly called "secondary" plant nutrient that is now been thought of as primary. Prof Steve Mc Grath, a sulphur expert from Rothamsted Research, was the co-author of a number of papers[1] that reviewed available field data at the IFS conference. He has the story for New Ag International.

[1]F.J.Zhao, S.P. McGrath, M.M.A. Blake-Kalff, A. Link & M. Tucker. Crop responses to S fertilization in Europe. S.P McGrath, F.J. Zhao, M.M.A. Blake-Kalff, History and outlook for S fertilizers in Europe.

Sulphur (S) is one of the oldest elements known to man! It is the 13th most abundant element in the earth's crust. S deficiency was first detected in Ireland in the 1970s, and has since spread to many crops of oilseed rape and later cereals in France Scotland, England. In the 1990s, S deficiency developed in cereals in Germany, and the UK.

AN ELEMENT CENTRAL TO PROTEIN SYNTHESIS

Some people may have only recently rediscovered the role of sulphur as a major plant nutrient. However the fundamentals have never changed: sulphur is essential for the production of cysteine & methionine, two amino acids that in turn are the building blocks in the synthesis of many proteins. All enzymes require S, including RuBPC (for CO2 fixation). It is essential to chlorophyll synthesis (although not a constituent of chlorophyll), enters in the composition of vitamins (co-enzyme A, biotin and thiamine in vitamin B1), it is required for some lipids in membranes; it is involved in some redox reactions in the cell and has a key role in stress resistance. Last but not least in this non-exhaustive list, sulphur promotes nodulation for N fixation by legumes (Fe - S cluster in Nitrogenase). In other words, sulphur is part of the makeup of every living organism.

SULPHATE IN SOILS: THE MOST IMPORTANT CHEMICAL FORM FOR CROP NUTRITION

The amount, chemical forms and distribution of S varies in soils across different management, climatic and geochemical conditions. Both inorganic and organic forms exist in soils, with organic S normally con-

AN INTERVIEW WITH

Alexandre Macedo, National Sales Manager, Speciality - Hydro Agri Brazil

competitive, where subsidies does not exist. The only way to succeed in Speciality sales is to show a real benefit to growers. We are very glad, Hydro and SQM are the leaders in services and both companies have a tradition on scientific trials with our main products.

But it is not enough, Brazil is a very large country, with many different soil types and climatic conditions, and so crop needs vary from region to region. Three main pillars make our difference in the market.

First, highly trained sales force, where all sales people are agronomists, who are seen as nutritional specialists in the field. Then the product portfolio, where Hydro and SQM offer a complete line for fertigation, dry applied and foliar fertilizers with a superior quality. Third and not less important, the logistics offered by the commodities operation, with discharge ports and warehouses spread into the main agriculture areas in Brazil.

After a first year of Hydro and SQM having joined forces, we have reached a very clear leading position not only in the fertigation market, but also on the dry applied Specialities, based on Nitrates from both companies.

The outlook for the Brazilian Agriculture market is very optimistic. Last year, the total fertilizer market has grown by about 3 Mill tones (+- 18%). After the devaluation, Brazilian exports became very competitive in the international market, which has stimulated many export crops. Fruits, vegetables and cereals are the main consumers of Speciality Fertilizers. It is very difficult to measure potentials here, because the market for Specialities is still in the beginning of its growth curve, but we expect that in 5 years time, the market for Chilean Nitrates, Calcium Nitrate, Potassium Nitrate and Water Soluble NPK's can grow up to 300 KT and become the third largest, just after USA and China."

"After a first year of Hydro and SQM having joined forces, we have reached a very clear leading position"

NUTRIENT?

Sulphur deficiency symptoms on winter wheat in the Broadbalk experiement, UK, in May 2002.

Photo courtesy of: Rothamsted Research

sisting of the larger pool. However, plants take up the sulphate form of S via roots and this is therefore the most important form in soils from a nutritional point of view. Soils receive S from wet and dry deposition, which either exists or is transformed into sulphate, and sulphate or elemental S can be intentionally added to soil in fertilisers. Sulphate is also the form that is prone to being leached out of the rooting zone. Where elemental S fertilisers are used, their oxidation is a biological process, but the rate is often limited by the physical form of elemental S in the soil. Sulphur in soils undergoes microbial immobilisation and mineralisation concurrently. The net outcome of these two processes varies with time and net mineralisation is difficult to measure and to predict.

The forms of S in soil organic matter are both heterogeneous and complex. It remains unclear how different fractions of organic S are interrelated in the turnover processes. Microbial biomass-S is probably the most active component of soil organic S. Methods which fractionate soil organic S into different pools according to their biological and biochemical lability need to be developed, and these may be more informative. Data on soil S turnover from field

continues on page 72

A value to cost ratio of up to 50:1 in sulphur applications!

studies, which are essential for developing and validating models, are scarce and scattered. Occurrence of S deficiency is likely to be increasingly found particularly on light or shallow soils with low organic matter content.

OILSEED RAPE: ONE OF THE MOST RESPONSIVE CROPS

In terms of S requirements and responses, research has focused mainly on oilseed rape, cereals, and grass. There is a scarcity of yield response data for other arable crops and vegetables, but we do have indications of their S requirements (see Table). Brassica crops have a high demand for S, requiring 50-70 kg S/ha. As shown in the table the distribution of S between the marketable and residual parts also varies between crops.

Oilseed rape is among the most responsive crops to S. Widespread S deficiency in oilseed rape was reported in France in the 1980s, with S applications increasing yield by an average of 12%. Between 1987 and 2002, data from 29 out of 78 available field trials (37%) on winter and spring oilseed rape in the UK showed a significant yield response to S additions. The frequency of S responses was even higher in Germany. Between 1991 and 1995, 32 out of 62 field trails (52%) conducted showed a significant yield increase due to S applications. It is also clear that S responsiveness became much more common in 1993-1994 in Germany than in the two previous seasons. In the S responsive trials, yield increases in response to S application varied between

Total S uptake in kg/ha of various crops, divided into the portions of each crop that are marketed or not

	Non-marketable	Marketable
Lettuce	6.4	3.8
Carrot	5.3	5
Beans	6	7.6
Peas	6	8.5
Wheat	6	9
Sugar beet	11	5
Red beet	10.8	7.5
Leek	15	13
Onion	7.5	32
Swede	23	27
Cabbage	32	22
Oilseed rape	45	14
Broccoli	46	14
Brussels sprout	44	29

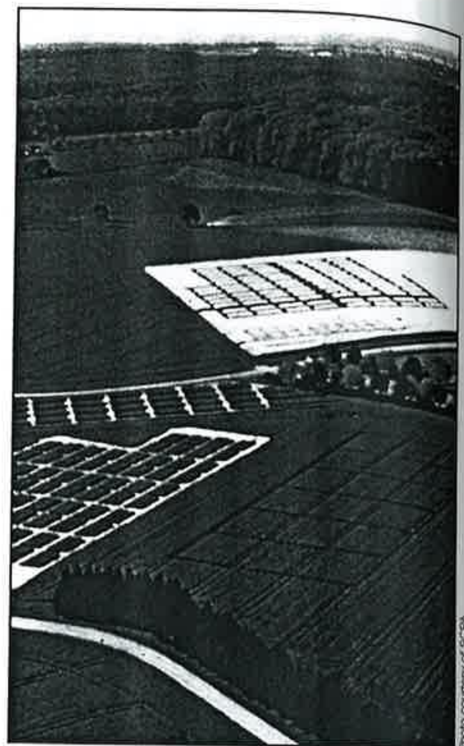


Photo courtesy of SCPA

0.15 to 2.7 t/ha, with relative increase of 4 - 415%. Yield responses of greater 50%, which are not uncommon in both UK and German trials, are of a similar size as the responses to N. The majority of responsive trials responded up to an application rate of 30 kg S/ha. Even with the current depressed grain price, the ratio of yield benefit to the fertiliser cost in the responsive trials is in the range of 3:1 to 50:1.

CEREALS: THE POSITIVE INTERACTION BETWEEN SULPHUR & NITROGEN

In the last 15 years, 12 out of 25 trials with either winter or spring barley in England and Wales have also shown a significant yield response to S. In total almost half of the trials in the UK and Ireland showed significant yield increases to S addition. In Germany, the only available data set showed a significant yield response in 2 out of 9 trials conducted in 1999 with winter barley. Yield increases varied from 0.26 to 2.19 t/ha, or 5 to 32% on a relative basis. For winter wheat in the UK, 20 out of 72 trials (28%) conducted between 1993 and 2002 showed a significant yield increase in response to S application. The S responsive sites were located mainly in the areas with low S deposition and with light textured soils or shallow calcareous soils. In Germany, 3 out of 18 trials (17%) between 1998 and 2002 produced a

Sugar beet: A new opening for sulphur products?

significant yield response. Yield increases in wheat were similar to those recorded in barley, with between 5 and 30% increases in most cases. The lower frequency of a response to S in wheat compared to barley in the UK may in part be due to the fact that barley is usually grown on light textured soils, which are more likely to be deficient in their S supply.

In most cases in those trials that were S responsive, 20 kg S/ha in the form of sulphate was found to be sufficient for wheat and barley, though very high-yielding crops may need more than this. The magnitude of the yield response also depends on N supply. Greater responses to S are found at higher N rates and this suggests that there is a positive interaction between N and S. It is also clear from trials that the full benefits of the applying higher rates of N are not obtained when no S is applied. This means that S deficiency will result in lower N utilisation efficiency, and consequently a higher risk of N losses to the environment.

MORE RESEARCH NEEDED ON LEGUMES, POTATO & VEGETABLES

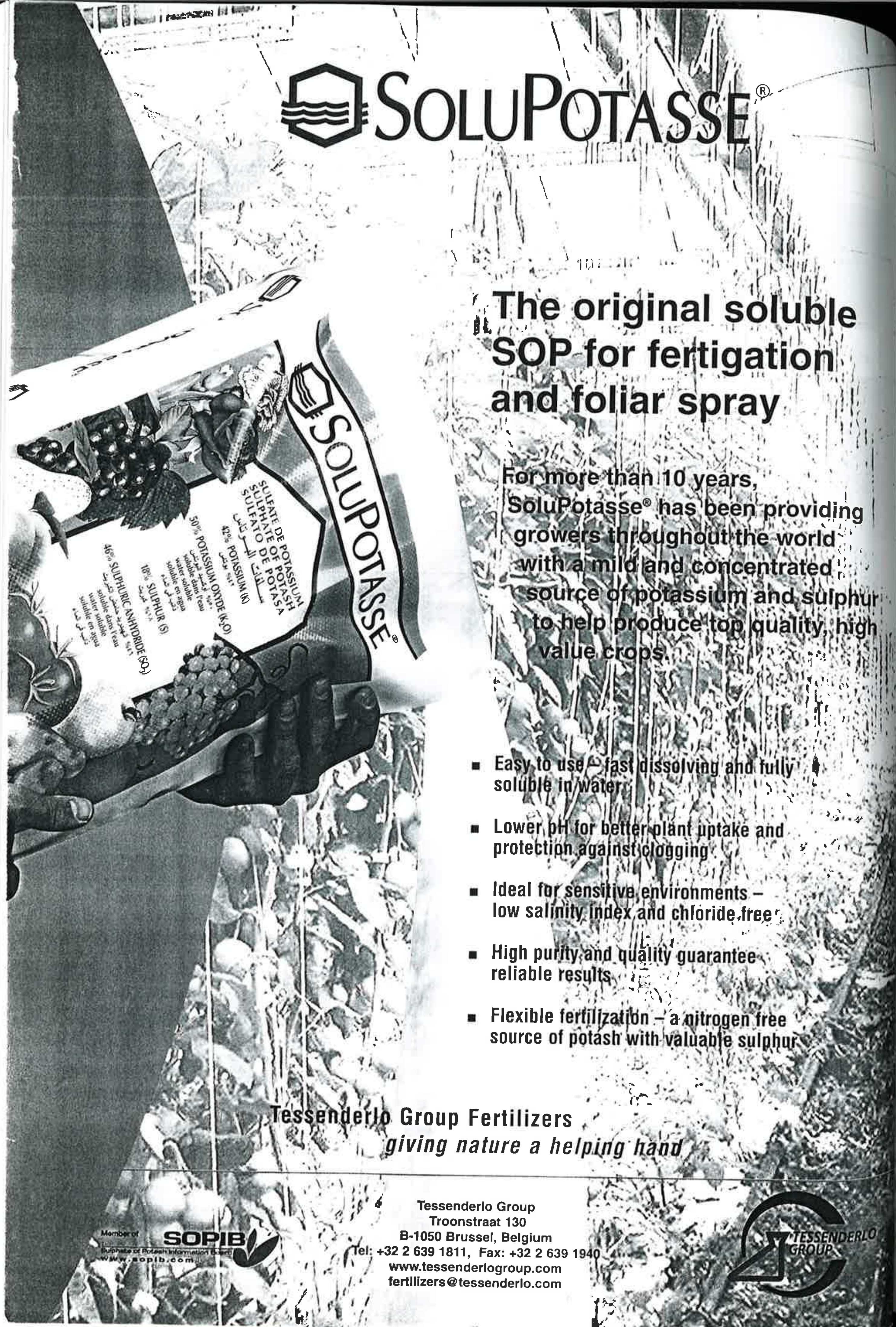
Apart from grass where a number of trials have been conducted as early as 1974 (Ireland) with positive response, there has been less research on S responses in other crops in Europe. Application of S (25 kg S/ha) increased sugar beet root yield significantly by 25% at a low S site in England in the 1998 season, but had no significant effect in the 1999 season. In Germany, sugar beet root yield was increased by 3-6% in 3 trials in 1998. Legumes have a relatively low requirement for S, and there have been few reports of S deficiency in legume crops in Europe. It has been shown that S fertilisation of field beans and peas in Denmark increased the essential amino acids compared to those in a reference protein, and the 'biological value', in feeding trials. These results indicate that maintaining a sufficient S supply to legumes is important for the nutritional quality of legume grains. Further research is needed in future to investigate yield and quality responses to S in legumes, potato and vegetables.

ENHANCING CROPS' QUALITY & NUTRITIONAL VALUE

For wheat, deficiency of S can result not only in yield losses, but also in poor breadmaking quality. In the UK, loaf volume was shown to correlate more strongly with grain S concentration than with grain N concentration. Addition of 46 kg S/ha also increased loaf volume by 6% in German trials.

Application of S may also affect the quality of barley for malting. The effect of S on grain N concentration is probably due to a dilution of N in the crop, which resulted from growth stimulation and yield increase in response to S. This lower N concentration in grain can be beneficial to malting quality.

The nutritional quality of S-deficient grass silage is poor. For animal feeding, a N:S ratio below 15:1 is considered satisfactory. Applications of S increase the concentration of S and decrease the N:S ratio. In addition, S applications also increase the proportion



of total N in grass present as protein-N, and decrease the contents of nitrate and free amino N. These effects are beneficial for animal nutrition.

SPRING APPLICATION OF SULPHUR: OFTEN THE BEST SOLUTION

Many of the reported trials used sulphate-containing fertilisers. However, elemental S forms are also available. These need to be oxidised to sulphate before plants take them up. The rate of oxidation depends on a number of factors, but often the key is the particle size of the elemental S. Larger particles are oxidised too slowly to provide a sufficient S supply to annual arable crops.

Farmers and Growers will have little choice but to increase their application of appropriate sulphur fertilisers.

A sugarcane field in Guangxi Province, China, with and without sulphur fertilizer applied.

In contrast, elemental S in the form of a fine powder, has been shown to be oxidised rapidly in soils. However, applying 30 kg/ha of S in this form can be difficult, even in spray form, and it is also more expensive than sulphate based fertilisers. Because of the risk of leaching losses, sulphate should ideally be applied when the crop needs S in the spring. There are strong reasons for both N and S to be applied together: from the point if view of soil chemistry, both nitrate and sulphate are prone to leaching, and from the consideration of crop physiology, as N and S assimilation are inter-dependent. On wheat, late foliar sprays containing sulphate give little uptake, and almost none when elemental S is sprayed. So spraying late in the season is an unreliable way of supplying S for yield and quality of the crop.

With atmospheric inputs of S set to continue decreasing further in Europe, the deficit in the S input/output is likely to increase. Occurrence of S deficiency is likely to be increasingly found on light or shallow soils with low organic matter content, in areas of low atmospheric deposition of S and with excessive winter rainfall. In order to reduce the imbalance in the sulphur input/output, Farmers and Growers will have little choice but to increase their application of appropriate sulphur fertilisers. Sulphur has an ever-stronger claim to be a nutrient on a par with the other primary nutrients! ■

LINK

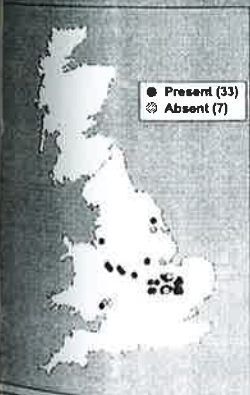
SUSTAINABLE ARABLE LINK PROGRAMME

Combating insecticide resistance in peach-potato aphids in the UK

Steve Foster, Ian Denholm and Alan Devonshire

Red and green forms of *Myzus persicae*.

Application of insecticide to detect resistance in *M. persicae*.



Presence of *M. persicae* with knock-down (kdr) resistance to pyrethroids in samples collected from field crops in 2000.

THE PROBLEM

The capacity of insects to develop resistance to insecticides poses a severe challenge to effective crop protection. It threatens the sustainability of crop production, and by prompting increased use of insecticides, exacerbates possible side-effects on the environment. In the UK, difficulties in controlling peach-potato aphids, *Myzus persicae*, on field and glasshouse crops exemplify such concerns. There is consequently an urgent need to manage resistance by more judicious, scientifically-based insecticide use recommendations.

WHO WAS INVOLVED?

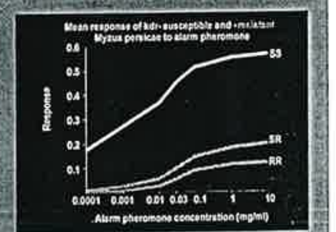
The work involved a multi-disciplinary team including two research organisations (Rothamsted Research and ADAS Consulting Ltd), a commodity group (British Potato Council), two industrial consultants (Agrovista UK Ltd and QV Foods Ltd) and an agrochemical company (Syngenta).

RESEARCH FINDINGS

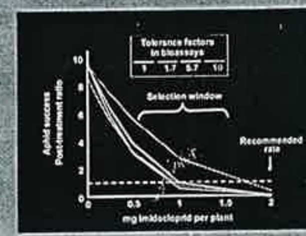
The project (completed in October 2001) identified several factors influencing the selection and management of resistance in *M. persicae*. These included a clearer definition of the incidence and practical implications of different resistance mechanisms, and identification of possible fitness costs associated with resistance that could influence its frequency in the field. The project findings led directly to clear recommendations for the management of resistance in this pest.

POTENTIAL IMPACT AND EXPLOITATION

Our findings and recommendations have been disseminated widely through scientific publications, publicity leaflets, articles in the farming press, conference lectures and personal contact with consultants and growers. The project has also helped the UK Insecticide Resistance Action Group (IRAG) to provide informed guidance on resistance problems to growers, advisors, industrialists, and staff at Defra-PSD involved in policy-making and pesticide approval.



Pyrethroid-resistant *M. persicae* show a reduced response to aphid alarm pheromone. This could make them more vulnerable to attack by predators and parasitoids.



Efficacy of imidacloprid against *M. persicae* that are susceptible or tolerant to this insecticide in laboratory bioassays. Existing levels of tolerance are only significant when imidacloprid is applied at rates lower than those recommended for field use. Measures are urgently needed to prevent further increases in tolerance to this and related neonicotinoid insecticides.

For further information contact:
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