FOCUS ON FARMING PRACTICE - AN INTEGRATED APPROACH TO SOLVING CROP PROTECTION PROBLEMS IN CONVENTIONAL AND ORGANIC AGRICULTURE.

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ABSTRACT

Five years evaluation of farm scale organic trials have demonstrated the importance of crop rotation, cultural and biological control in suppressing crop antagonists. Such a systems approach appears to provide opportunities for conventional agriculture to use inputs in a more controlled and precise manner.

In order to investigate an integrated approach to crop protection on a commercial basis a farm scale trial was established, using technical and financial support from a crop protection specialist and fertiliser producer, along with expertise and land provided by a major farming company. The 150 acre farm was established in 1993 using a 7 course integrated rotation. The trial will evaluate the economics, technical feasibility and environmental impact of an Integrated Farming System and compare this with conventional and organic practice at the same site.

INTRODUCTION

CWS Agriculture, the farming division of the Co-operative Wholesale Society, farms 20,000 ha of land at 27 locations around Great Britain using agrochemicals and fertilisers characteristic of West European agriculture. In the late 1980's British retailers reported a rapid increase in demand for organic produce leading to predictions that this market could account for 20% of produce by the year 2000. Literature searches revealed that both the technical viability and financial performance of this farming system was poorly documented. In order to ascertain this information as well as to gain practical experience, 105 ha were put into organic conversion in the spring of 1989, achieving full approval to Soil Association standards by 1991 (Anon, 1992). This experiment continues and full results will be reported when the 7 course rotations are completed.

The experimental acreage was increased by a further 60 ha in 1993 to examine the practical management and economic consequences of an Integrated Farming System. The principle requirements of Integrated Farming are defined by the International Organisation for Biological Control (El Titi *et al.*, 1993).

Practical and financial support is provided by fertiliser manufacturer Hydro Agri and crop protection specialists Profarma. This collaboration was considered necessary due to the high technical requirement which integrated farming demands, particularly in relation to the optimal and precise use of fertilisers and crop protection products.

METHODS

The organic and integrated farms were both set up to investigate the systems approach to suppressing crop antagonists. This involves using cultural, biological and mechanical techniques. The organic system is limited to these alone while the integrated system permits targeted intervention with crop protection products and fertilisers. The use of these products is only permitted where yield loss is likely to be significant. Diagnostics, early warning systems and thresholds form an important part of the decision making process with patch spraying and low dose treatment to remove only the damaging portion of the pest population commonly practised. These techniques are compared with conventional farm practice at the same site.

The three farming systems rely on contrasting techniques to achieve a common aim: maximum profitability of the whole rotation whilst sustaining or improving the land for future cropping.

All operations are logged and costed using the Central Association of Agricultural Valuers Guide To Costings (Anon, 1994) adjusted to take account of local conditions. Inputs are costed at purchase price plus application costs. The key aspects of each system are set out as follows:

<u>Crop Rotation</u>

								Area (ha)
Organic (mixed)	Ley	Ley	Ley	Wheat	Oats	Beans	Wheat	20
Organic (stockless)	G/M	G/M	Wheat	Oats	Beans	Wheat	SAS	25
Integrated	Grass/ Clover	Grass/ Clover	Wheat	SAS	Wheat	Beans	Wheat	28
Conventional (integrated rotation)	Grass	Grass	Wheat	SAS	Wheat	Beans	Wheat	28
Conventional (conventional rotation)	OSR	Wheat	Beans	Wheat	SAS	OSR	Wheat	15

(OSR - oilseed rape, SAS - set-aside, G/M - green manure)

Crop Varieties

Organic: Disease resistance and competitive ability (height and ground cover) to suppress weeds are of primary importance. Milling varieties of cereals to achieve organic premiums.

Integrated: High yielding varieties with good disease resistance, standing power and vigour to compete with weeds. Feed varieties only.

Conventional: High yielding varieties which respond to crop protection and fertiliser inputs. Feed varieties only.

Cultivations

Organic: Ploughing essential to destroy weeds and bury weed seeds below the germination zone.

Integrated: Light cultivation post harvest to stimulate volunteer and weed seed germination, and incorporate trash. Crop established using one pass Rau Rotosem, which loosens, cultivates, drills and packs. Ploughing once per rotation if weed seed burden becomes high in the top 10cm soil.

Conventional: Plough 1 year in 3 with heavy discing in the intervening years.

Crop Establishment

Organic: Drilling seldom before first week of November to reduce autumn weed strike and barley yellow dwarf virus (BYDV) infection through aphid colonisation. The lower yielding potential of organic crops means that little loss is likely to be incurred by such a delayed drilling. Higher seed rate to compensate for poorer germination conditions, slug damage and loss of plants through mechanical weeding. Good plant populations required to compete with weeds and compensate for lower tiller numbers due to limited N availability.

Integrated:

Crops following grass/clover: Drilling usually the last week of September to take up mineral N released by sward destruction. Weed competition is potentially lowest at this point in the rotation.

Other crops: Drilling date targeted at mid to late October with higher seed rates as for the organic system.

Conventional:

Mid-September to mid-October to ensure crop establishment while soil and weather conditions are good.

<u>Crop Protection - Weeds</u>

Organic:

Mechanical only where conditions are suitable, preferably autumn and spring. Larger weeds require 2 passes at right angles to each other. Tap rooted plants are not susceptible. Lower N availability restricts growth of aggressive species, and reduces potential seed shed.

Integrated:

Threshold based systems using weed numbers per m^2, or crop equivalent indexes while considering the risk of seed with long viability being shed causing problems later in the rotation. Volunteers and weeds germinated by post harvest cultivation are sprayed off with low rate glyphosate. A range of strategies are being examined including use of low dose contact only materials, spring applied to suppress weeds; combined techniques of low dose herbicide in conjunction with mechanical weeding. Products which are selective, of low leachability, volatility, mammalian toxicity and persistence, are preferred. The protection of water quality is cited as a major consideration on this site since the soil is prone to cracking and the fields drain directly into the River Sence.

Conventional:

Post emergence autumn applied residual materials, at reduced rates where appropriate, followed by treatment of specific problems with spring applied contact products.

Crop Protection - Diseases

Organic: No treatments used but very little disease generally experienced due to less 'soft' growth and more open canopies.

Integrated: Resistant varieties and precise N use. Diagnostics and early warning systems used and where disease pressure is likely to be high a low dose is applied. Crop monitoring between growth stages 32 and 39 determine the requirement for flag leaf sprays using between half and full rate.

Conventional: Multi low dose approach using protectant and curative fungicide mixtures. First applications in the autumn and at regular intervals through to flag leaf. Ear wash sprays where crop yield potential is high and disease pressure evident.

Crop Protection - Pests

Organic: Biological control only. No crops have been lost to pest attack to date. Pest populations appear to build up in large numbers on individual plants, but the crop as a whole remains relatively clean. Slugs have caused crop failure on heavy and wet areas which could not be rolled after sowing. Cereal crops tend to mature earlier than conventional crops and consequently aphid numbers seldom reach yield threatening levels.

Integrated: Threshold levels observed for aphids, bulb fly, orange blossom midge and slugs. Populations are monitored by counting individuals on plants (aphids), extracting eggs from soil samples (wheat bulb fly) by catching adults using attractive sticky cards (orange blossom midge) or using unbaited activity monitors prior to sowing (slugs).

Conventional: Treatments applied at first sign of pest attack. Where fungicide or herbicide applications are scheduled low rate insecticide is incorporated in the mixture.

Crop Nutrition

Organic (mixed):	Grass/clover leys, composted farmyard manure (FYM) from the suckler herd and leguminous break crops. Green covers during the winter period.
Organic (stockless):	Grass/clover leys cut and mulched. Cereal crop prior to set-aside period undersown with grass and clover to achieve maximum N fixation and crop biomass. Leguminous break crops. Permitted products of low solubility e.g. rock phosphate to maintain P and K levels.
Integrated:	Nitrogen targeted to expected crop yield using a computer based field specific prediction system called "Extran Plan" (Anon, 1991-92). First application is made in mid March using NPK compound fertiliser followed by a second application mid April of ammonium nitrate. The third and final application is fine tuned using a chlorophyll meter and tissue tests. Mineral N measurements taken post harvest to ascertain accuracy of strategy and mid February to establish soil levels prior to fertilisation. Experiments are underway to measure the amount of mineralisation which occurs after different cultivation techniques to be included in the calculation and atmospheric deposition is being recorded. P + K levels are maintained using the Field Nutrient Balance Scheme which replaces losses through crop off-take.
Conventional:	N fertilisation for optimum yield. Standard farm practice based on historical experience. Product choice is based on price, usually Urea for early dressings and applied in 2 splits. Ammonium nitrate for applications after mid April. Rotational P + K fertilisation.

RESULTS AND DISCUSSION

It is inappropriate to make judgements on the economic performance of a systems approach until at least one full rotation is completed. Similarly the condition of soil particularly in reference to fertility, % organic matter content and weed seed bank can only be measured at a fixed point preferably at the beginning and end of each rotation. The organic rotation is currently in its fourth year of full conversion with a further three years cropping to complete the rotation. The integrated and conventional comparison is currently in the second year with a further five years to complete the rotation. At the present time it would appear that under a range of conditions both systems are technically feasible and crops can be grown with limited yield penalties. Lower yields can be tolerated in the organic system since premium prices are obtainable, while the precision use of crop protection inputs and fertilisers in the integrated system should reduce production costs while maintaining yields close to conventional levels. The current relatively high commodity prices favour the conventional system since it increases the cost:benefit ratio of each input. Should the predicted decline in prices occur the integrated system is expected to show an improved margin.

Information is also being sought on a range of environmental factors to ascertain the impact of the farming systems as the rotations progress. Measurements are being made of flora numbers and diversity, invertebrates, small mammals, molluscs, earthworm numbers and biomass, bird census and pesticide and nitrate measurements in water courses on the site.

CONCLUSIONS

The results obtained through the Focus on Farming Practice project will provide UK agriculture with commercial and farm scale data concerning economics, technical feasibility and environmental impact of organic, integrated and conventional farming techniques. Such farm scale systems operated by an experienced farming company with technical support from commercial advisors is representative of that which is available to other UK farmers. These systems approaches deal with a range of interactions which occur in agro-ecosystems and attempt, through best farm practice and good science, to minimise the need for intervention. Where intervention is required the scale is measured.

Information derived through the experiments will be published as results become available.

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COMPARISONS OF ENERGY OUTPUT/INPUT OF CONVENTIONAL AND ORGANIC AGRICULTURE IN SCOTLAND AND IN HUNGARY

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ABSTRACT

A study was carried out in order to determine the differences in the energy ratio between organic and conventional farming systems in Scotland and Hungary, examining two crops, namely winter wheat and potatoes. Generally in both countries, conventional agriculture seemed to be more energy efficient particularly in the case of potatoes. In Hungary, conventional potato production was 20% more energy efficient than organic production. In Scotland this difference goes up to 100% owing to plant protection problems. On the other hand, Hungarian organic winter wheat is five times more energy efficient than conventional production. In Scotland, conventional wheat production is about 60% more energy efficient than organic producton.

INTRODUCTION

A study was carried out in order to determine the differences in the energy ratio between organic and conventional farming systems in Scotland and in Hungary.
The objective of this study was to find out whether organic farming systems could compete energetically with conventional farming systems looking at two crops, namely, winter wheat and potatoes.
There are various methods to measure energy use efficiency in agriculture. Energy ratio is the most important among them. The ratio deals with the use of energy in organic versus conventional farming systems leaving environmental aspects out of consideration. Despite its limitations the proponents of using the energy ratio technique view this method as the most satisfacotry means of measuring energy utilization efficiency.
(Pimental et.al, 1983, Singh 1993)

MATERIALS AND METHOD S

Wheat and potatoes

For this analysis, the data used came from wheat and potatoes grown under organic and conventional agricultural systems in south-east Scotland. For organic wheat production synthetic fertilisers were replaced with cattle manure, or with a combination of cattle and poultry manure. Data also came from wheat and potatoes grown under biodynamic and conventional agricultural systems in Hungary in the Gödöllõ Hills.

ASSUMPTIONS AND NOTES

Soil is energy neutral.

Size of field is 1 ha in all cases.

The use of fuel is only considered on the field.

Contribution of previous crop residue to fertility of current crop is zero.

In Scotland, organic production systems are more or less similar to biodynamic production systems in Hungary.

Energy content of 1 kg of seed - winter wheat: 18.4 MJ/kg, potato:3.18 MJ/kg

Energy content of 1 kg of synthetic fertilizer,N: 80 MJ/kg, P: 14 MJ/kg, K: 9 MJ/kg

The energy content of manure where calculated with the figures above for synthetic fertilizer.

For organic winter wheat grown in Scotland, energy ratios were calculated for the use of cattle manure and for the use of a combination of poultry and cattle manure.

For cattle and poultry manure, energy contents were calculated for both available and total nutrient contents. (Nutrients are available to the crop in the season of application, assuming no losses between store and soil.

The total energy required to supply one kg of pesticide has been estimated at about $101,3*10^6$ [Stout, 1979].

1 l of pesticide weighs 1 kg.

The energy content of preparation applied in Hungary by biodynamics is negligible.

The energy content of organic materials applied for plant protection is equal to the energy content of pesticides.

The fuel requirement of machines is the same in both countries.

The energy content of 1 l of fuel is:40 MJ/kg [Witney, 1988].

There is no energy content of by-products in this study.

The energy content of environmental pollution has been left out of consideration.

The energy content of micro elements in manure is negligible.

Scottish data are average of 1994 from south-east Scotland; hungarian data are from the area of the Gödöllõ Hills during a year.

Conclusions were drawn from yield performance concerning energy efficiency, labour requirements have not been taken into account.

RESUL TS & CONCLUSIONS

Conventional agriculture is more energy efficient in both countries, particulary in the case of potatoes. In Hungary, conventional potatoes are 20% more energy efficient than organically produced potatoes. In Scotland, this difference goes up to 100% owing to plant protection problems. Hungarian organic winter wheat is five times more energy efficient than the conventionally produced wheat. In Scotland conventional wheat production is about 60% more energy efficient than organic wheat production.
Conventional winter wheat in Hungary was about four times less energy efficient than Scottish wheat owing to financial problems in Hungary, where there is a lack of nutrient supplementation in organic farming. Therefore, the inputs decreased and outputs remained the same, which resulted in a higher energy ratio. After a few years, the soil in the organic farming system in Hungary will require more nutrient inputs to obtain the same outputs which wil cause the energy ratio to decline gradually. Conventional potatoes gave the same results in both countries. Taking all factors into account, organic farming systems seem

to be more energy efficient in Hungary, while conventional farming systems gave similar results in both countries.

TABLE 1. Energy ratio in Hungary

	biodynamic	conventional
Potatoes	2.88	3.04
Winter wheat	9.00	1.74

TABLE 2. Energy ratio in Scotland

	organic	conventional
Potatoes	1.709 (a)	3.25
	3.242 (b)	
Winter wheat	3.041 (a)	5.74
	2.932 (b)	
	5.902 (c)	
	5.504 (d)	
	2.864 (e)	
	2.767 (f)	
	4.832 (g)	
	4.562 (h)	

Notes to table 2.

Energy ratio is calculated,
potatoes (a): for the total nutrient contents.
(b): for the available nutrient contents.

winter wheat (a): for the total nutrient contents. There is no plant protection. Only cattle manure applied.
(b): for the total nutrient contents. There is a plant protection with Kumulus D.F.
(c): for the available nutrient contents. There is no plant protection. Only cattle anure applied.
(d): for the available nutrient contents. There is a plant protection with Kumulus D.F. Only cattle manure applied.
(e): for the total nutrient contents. There is no plant protection. Combined cattle manure and poultry manure.
(f): for the total nutrient contents. There is a plant protection . Combined cattle manure and poultry manure.
(g): for the available nutrient contents. There is no plant protection. Cattle and poultry manure applied.
(h): for available nutrient contents. There a is plant protection with Kumulus D.F. Applied cattle and poultry manure.

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EFFECT OF DENATONIUM BENZOATE ON *MYZUS PERSICAE* FEEDING ON CHINESE CABBAGE, *BRASSICA CAMPESTRIS SSP. PEKINENSIS*

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ABSTRACT

Denatonium benzoate which is known to act as an antifeedant against mammals was shown to have a similar effect on *Myzus persicae*, on Chinese cabbage plants in the laboratory. Aphids on plants sprayed with distilled water lived longer and produced more nymphs per plant than aphids on plants sprayed with denatonium benzoate at concentrations varying from 0.5 to 250 ppm. Honeydew production was less on leaves and leaf discs treated with denatonium benzoate than on untreated leaves, and leaf discs. A choice test showed that the aphids tended to move on to untreated halves of leaf discs.

INTRODUCTION

Denatonium benzoate, marketed as bitrex™ (by Macfarlan Smith Ltd, Edinburgh) is an inert odourless synthetic chemical with an extremely bitter taste. It is commonly used as an additive to prevent people ingesting or chewing a wide variety of hazardous chemical products such as detergents, disinfectants, and pesticides. Denatonium benzoate has been shown to act as an antifeedant against rabbits (Menu, 1993), and it is sold for use against a variety of mammals including horses, deer, and rats. However, the effect of denatonium benzoate on insects appears to have received little attention, although there is currently a great deal of interest in other compounds such as azadirachtin, partly because of their effectiveness as antifeedants against commercially important insect pest species (Saxena, 1989). *Myzus persicae* (Homoptera : Aphididae), the peach potato aphid, is an important virus vector, and has an ability to develop resistance rapidly to successive groups of insecticides (Wege, 1994). Therefore the use of antifeedants may be a substitute for conventional insecticides. *M. persicae* is also a good subject for research, as it can be reared easily in the laboratory.

The aim of this study was to determine whether denatonium benzoate has an antifeedant effect against *M. persicae* on Chinese cabbage, *Brassica campestris ssp. pekinensis*. Experiments were carried out to determine the effect of denatonium benzoate on the survival of aphids and their production of nymphs. Honeydew production was monitored as an index of feeding rate, and a choice experiment was undertaken to determine whether aphids preferred to feed on untreated leaves than on leaves treated with denatonium benzoate.

MATERIALS AND METHODS

To determine whether denatonium benzoate affected the survival of *M. persicae* and number of nymphs produced, three-week old potted Chinese cabbage plants (cv. Nepos ez F1) were sprayed with distilled water or denatonium benzoate solution (0.5, 5, 50, 100, and 250 parts per million (ppm)). The wetting agent agral™ was added to the sprays at a rate of 0.1 ml/litre. Five plants were used for each treatment. Ten one-day old *M. persicae* nymphs were placed on each plant, and the number surviving was recorded each day until all of the original aphids were dead. Once the aphids began to produce nymphs, the number of nymphs produced was also recorded each day, and the nymphs were removed after counting.

Honeydew droplets excreted by aphids feeding on leaves and leaf discs were detected using ashless 125 mm diameter filter papers stained with bromocresol green indicator solution (Banks & Macaulay, 1964). For the experiment with leaves, five mature Chinese cabbage leaves were dipped in distilled water with agral or 250 ppm denatonium benzoate solution with agral, and three one-day old aphid nymphs were placed on the underside of each leaf. The leaves were placed in water in glass vials, so that they projected over a stained filter paper. For the experiment using leaf discs, five 20 mm diameter Chinese cabbage leaf discs were dipped in distilled water with agral or 0.5, 5, 50, 100 and 250 ppm denatonium benzoate solutions with agral and placed on hydrogel (Erin™ waterwell) in 35 mm diameter petri dishes. Three one-day old nymphs were introduced on to each leaf disc, then the petri dishes containing the leaf discs were suspended upside down over stained filter paper. The number of honeydew spots on each filter paper and the number of nymphs remaining on each leaf or leaf disc were counted after 24 hours.

For the choice experiment 35 mm diameter leaf discs were taken, with the mid rib bisecting the disc. One half of each disc was dipped in distilled water with agral and the other in denatonium benzoate (0.5, 5, 50, 100, and 250 ppm) with agral, five discs were used for each concentration. The discs were placed in 35 mm diameter petri dishes containing hydrogel. Ten one-day old peach potato aphids were introduced on the mid rib and the number of nymphs on each half of the leaf disc were counted after 24 hours.

RESULTS

The aphids on the plants treated with denatonium benzoate survived to produce nymphs, and it was possible to relate the lifespan of the original aphids, and the number of nymphs they produced, to the denatonium benzoate concentration. The aphids on plants treated with distilled water had the highest average lifespan, and this decreased as the denatonium benzoate concentration increased. The average lifespan of the aphids was significantly longer on plants sprayed with distilled water and the two lowest denatonium benzoate concentrations (0.5 and 5 ppm) than on plants sprayed with denatonium benzoate at 100 ppm and 250 ppm (Table 1). Total numbers of nymphs produced on plants followed a similar trend, in that the total number of nymphs produced per plant was significantly higher on plants sprayed with distilled water than on plants sprayed with all of the denatonium benzoate concentrations (Table 1). Significantly more nymphs were also produced on plants sprayed with the lowest concentrations of denatonium benzoate (0.5 and 5 ppm) than on plants sprayed with denatonium benzoate at 50, 100 and 250 ppm, and the total number of nymphs produced on plants treated with 50 ppm denatonium benzoate was significantly higher than on plants treated with denatonium benzoate at 100 and 250 ppm.

TABLE 1. Average lifespan (days) of *Myzus persicae* and numbers of nymphs produced on denatonium benzoate treated Chinese cabbage plants. Values in the same row followed by the same letter are not significantly different ($p>0.05$). SED - Standard Error of the Difference

	Denatonium benzoate concentration (ppm)						SED
	0	0.5	5	50	100	250	
Lifespan	15.4 a	15.2 a	15.0 a	13.9 ab	10.8 b	10.4 b	1.6
Nymphs	303.6 a	253.8 b	231.2 b	186.4 c	124.8 d	123.8 d	12.9

The aphids on the whole leaves treated with distilled water produced a significantly ($p<0.05$) higher number of honeydew spots (8.6 ± 1.3 SEM) than the aphids on the leaves treated with 250 ppm denatonium benzoate solution (2.3 ± 1.1 SEM). The aphids on untreated leaf discs also produced more honeydew spots than aphids on leaf discs treated with denatonium benzoate, but there was no significant difference between any of the treatments (Table 2, $p>0.05$).

TABLE 2. Average number of honeydew spots produced by *Myzus persicae* on Chinese cabbage leaf discs during two 24 h periods. SED - Standard Error of the Difference

Day	Denatonium benzoate concentration (ppm)						SED
	0	0.5	5	50	100	250	
1	23.0	17.1	15.3	20.1	13.6	15.2	4.35
2	15.9	9.8	10.3	12.8	9.4	12.4	2.85

TABLE 3. Total number of aphids on halves of Chinese cabbage leaf discs treated with denatonium benzoate or distilled water, after 24 hours.

Denatonium benzoate concentration (ppm)	Total Number of aphids on leaf halves: D. benzoate treated	Total Number of aphids on leaf halves: Distilled water treated	p (χ^2)
0	33	27	NS
0.5	27	23	NS
5.0	17	32	<0.05
50.0	9	19	NS
100.0	10	22	<0.05
250.0	10	7	NS

In the choice experiment fewer aphids were found on the 5, 50, and 100 ppm denatonium benzoate treated halves of leaf discs than on the halves treated with distilled water, after 24 hours (Table 3). The differences were significant for the 5 and 100 ppm treatments. The aphids were able to leave the petri dishes during this experiment, and after 24 hours, less than the original ten aphids per dish remained in all of the denatonium benzoate treatments except 0.5 ppm. The greatest reduction in numbers of aphids was in the 250 ppm denatonium benzoate treatments, where only 17 out of the original total of 50 remained (although slightly more of those which remained were on the denatonium benzoate treated leaf halves). Some of the aphids moved into the control dishes.

CONCLUSION

The results of the experiment using sprayed plants suggest that treatment with denatonium benzoate would significantly reduce the rate of increase of aphid infestations, and on the basis of the measurements of honeydew production, the effect of denatonium benzoate appears to be a reduction of sap intake. The results of the choice experiment also suggest an antifeedant effect. However, the fact that the aphids would feed and produce nymphs on plants treated with denatonium benzoate indicates that it would probably not prevent them from colonising crops, and therefore would not prevent the spread of viruses. Denatonium benzoate can be taken up systemically by plants (Ondruskova *et al.,* 1992; Menu, 1993), and this may explain its apparently long-lasting effect on the aphids feeding on the sprayed plants in this study. Because of the bitter taste, denatonium benzoate could not be used on edible parts of crop plants, but if its effect was systemic, this could probably not be avoided. However, these results do suggest that if denatonium benzoate was used against mammals, for example to protect ornamental plants, it would also give some protection against insect pests.

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