The Occurrence, Characteristics, Distribution, Genetics, and Control of a Metalaxyl-Resistant Pathotype of *Bremia lactucae* in the United Kingdom

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Variation for sensitivity to phenylamide fungicides (also referred to in the literature as acylalanines, "acylalanine-like," acylanilines, anilides, and acylanilides) in members of the Peronosporales has been observed in three distinct circumstances. First, in laboratory studies with several species, isolates with decreased sensitivity (resistance) have been selected either with (2,5,7,26,27,43) or without (5,6,26,27,63,64) previous mutagenic treatment. Sometimes, such variants have lacked pathogenicity (7,64) or have been unstable (7,43), i.e., lost resistance in the absence of selection. Occasionally, resistance observed in vitro has not been reflected in vivo (3,6,43,64). Second, in the absence of imposed selection, and unassociated with disease control failure, field isolates of some species have shown considerable variation for sensitivity to the extent that some may be classed as resistant (12,13,17,42,62). Third, in association with intense selection and commercial control failure, highly insensitive (resistant) field isolates of several species have been recovered (1,4,8,11,15,16,18,25,30,33,38,40, 41,44,45,49,57,58,60,61,65,66); sometimes, there may be variation between such isolates in their degree of insensitivity (10,14,27,33,40,49,57). Whether the phenomena identified in these three circumstances are identical is unclear, but with the occasional exception of cyprofuram (10,37,46,47,49,59), cross-resistance to related fungicides appears to be observed regardless of isolate origin.

This paper is primarily concerned with the third set of circumstances and summarizes recent experiences in the United Kingdom with the occurrence, characteristics, and spread of a phenylamide-resistant pathotype of *Bremia lactucae* Regel (lettuce downy mildew). Information on the genetic control of phenylamide resistance is also presented, together with details of a strategy that has been introduced in commerce to combat the problem.

Historical perspective

Lettuce is the single most valuable vegetable crop in the United Kingdom (valued in 1985 at £174 million, or about $260 million) and is grown throughout the year under protection (glass or polyethylene) and from March to November in the field. Downy mildew is the most important disease of the crop, and although it may be troublesome throughout the year, it is a particular problem from August to November.

Prior to 1978, when metalaxyl (as Ridomil 25WP) first received commercial clearance for use on lettuce, chemical control of the pathogen was inadequate, relying on frequent applications of dithiocarbamates, particularly zineb (9). Concern over the residue levels in protected crops resulted in restrictions on the use of dithiocarbamates and a consequent further decline in efficacy.

The disease can be controlled in crops grown in heated glasshouses by raising the night temperatures of vented houses to lower the humidity, thereby maintaining conditions unconducive to infection (52). Because of the high energy costs, however, this is rarely considered economical. Other cultural procedures, such as crop clearing and programming irrigation to avoid prolonged leaf wetness, are helpful but insufficient to provide the degree of control required.

Breeding for resistance to *B. lactucae* has proceeded in Europe since the 1950s (22,23). Eighteen specific resistance factors are now recognized in lettuce cultivars, and at the present time, 50 different combinations of these occur in lettuce cultivars. Despite the fact that up to four different genes have been combined in a single cultivar, however, no combination has provided prolonged control. Variation for specific virulence in *B. lactucae* populations throughout Europe is considerable, and the use of new combinations of R factors results in the increased frequency of pathotypes carrying matching virulence. *B. lactucae* is predominantly heterothallic (51), and it is likely that sexual recombination is largely responsible for the encountered variation (39).

Against this background, it was no surprise that the exceptional control of lettuce downy mildew provided by metalaxyl (19,20,24,34,52) resulted in rapid adoption and extensive use of this fungicide after its commercial introduction in 1978. Initially, metalaxyl was sold as Ridomil 25WP and was used as a foliar spray or incorporated into peat blocks in which lettuce plants were raised before transplanting. In 1980, after the first experiences of control failure owing to resistance to metalaxyl in *Phytophthora infestans* (18,30,33,61) and *Pseudoperonospora cubensis* (38,45,58), Ridomil was withdrawn and replaced by Fubol 58 (10% metalaxyl plus 48% mancozeb) to be used solely as a foliar spray. Residual stocks of Ridomil continued to be used on lettuce, however; 9% of crops from which samples of *B. lactucae* were received between 1983 and 1985 had been treated with Ridomil, and 69% of these subsequently yielded metalaxyl-resistant isolates.

From 1978 to 1983, metalaxyl provided outstanding control of downy mildew in the U.K. lettuce crop. During this period, studies were conducted to ascertain what degree of insensitivity to the fungicide might result in a control failure and to determine the base-level sensitivity of the fungus population and any existing variability. In November 1983, a serious control failure owing to a high level of insensitivity to metalaxyl was confirmed.

Methods

Isolates obtained from commercial lettuce crops were cultured on the cotyledons of lettuce seedlings and subsequently tested for response to fungicide in vivo, specific virulence phenotype, and sexual compatibility type (SCT). Sensitivity to fungicide was determined by growing 30–40 lettuce seedlings in 7-cm crystallizing dishes containing nutrient absorbed in horticultural vermiculite and amended with fungicide concentrations ranging from 0.01 to 100 μg per milliliter. After 7 days of growth, when the cotyledons were expanded, the seedlings were inoculated by spraying with a spore suspension at a concentration of 10^5 per milliliter. Sporulation on untreated seedlings incubated at 15 C in an illuminated growth room commenced on some seedlings 5 days after inoculation; by 7–8 days, all seedlings bore sporophores. By taking sequential records, it was possible to derive a value for the mean reciprocal latent period of a batch of seedlings (reciprocals were used so that seedlings not bearing spores could be readily included in

the calculation). The value obtained for fungicide-treated seedlings was expressed as a percentage of the value for the untreated control. Thus, a value of 0% indicated that sporulation of the fungus was completely inhibited and a value of ≥100% indicated that the fungus was sporulating as well as or better than on the untreated controls.

Radiolabeling studies have indicated that over the duration of the test (3 weeks from sowing), the concentration of metalaxyl in the cotyledons remains constant and is consistently about 70% (μg/g fresh weight) of that applied in the nutrient (μg/ml) (67,68).

Sporulation of sensitive isolates of *B. lactucae* is completely inhibited on seedlings grown in the presence of concentrations >0.1 μg per milliliter of metalaxyl. At 0.01 μg per milliliter, some variation in sensitive isolates is observed, with inhibition ranging from 30 to 100%. On average, sensitive isolates have an ED_{50} value of about 0.005 μg per milliliter. Phenylamide-resistant isolates of *B. lactucae* sporulate as freely on seedlings grown in the presence of 100 μg per milliliter of metalaxyl as they do on untreated seedlings. Routine tests on field isolates included a standard sensitive control isolate as well as a standard resistant isolate after resistance was confirmed. Two replicates of each fungicide concentration were used.

Methods for determining specific virulence and SCT are described elsewhere (50,51,53,54).

By means of a bioassay developed to determine the metalaxyl concentration in plant tissue (68), it was concluded from field studies that insensitivity in *B. lactucae* to 0.1 μg of metalaxyl per gram fresh weight could result in control failure. This was the concentration in lettuce plants at the critical time of 7 days after spray application. (Under ideal conditions, the latent period of the fungus is 7 days, sprays are applied every 14 days, and the harvest interval is 14 days.)

Between 1979 and 1981, 30 isolates of the fungus were tested for sensitivity to metalaxyl. Twelve of these originated from crops where control with metalaxyl was said to be inadequate, but none were capable of sporulation on seedlings treated with ≥0.1 μg per milliliter of metalaxyl.

The occurrence of resistance

After a 2-year lapse, routine testing of field isolates recommenced in September 1983. Isolates confirmed as highly resistant to metalaxyl were first received in November 1983 from several sites in an area of intensive lettuce production near Preston in Lancashire. Spectacular control failure was experienced throughout the region in glasshouse lettuce crops, and over the following 12 months, resistant isolates were recovered from sites within a 20-km radius of the first outbreaks. All isolates received from outside this area before November 1984 were sensitive. This outbreak of resistance was associated with intense selection, with at least 5 years of continuous fungicide usage, including pure metalaxyl (as Ridomil).

In November 1984, reports were received of control failures in crops in other production areas (North Yorkshire and Humberside), but no isolates for testing were recovered from samples received. In the same month, resistance was confirmed at two sites (Lincolnshire and Warwickshire) remote from the initial outbreak; in both cases, the growers had recently bought plants for transplanting from Humberside, a suspected area. During 1985, resistant isolates were received from sites in all the major lettuce-producing regions (with the exception of Kent in the extreme southeast), and resistant isolates continued to be obtained during 1986. There was evidence that the rapid spread was a consequence of the distribution of plants from specialist plant raisers to growers throughout the country.

Characteristics of resistant isolates

All of the more than 120 resistant isolates tested sporulated freely on seedlings grown in the presence of the highest concentration of metalaxyl used (100 μg per milliliter). A sample of 15 resistant isolates from different sites all proved to be of B2 SCT. All resistant isolates tested (originating from 98 different sites) proved to be identical for specific virulence. Resistant isolates were virulent on R factors 1–10 and 12–15 but lacked virulence for R11, R16, R17, and R18. This virulence phenotype is equivalent to Dutch race NL10 and during 1983–1984 was also the commonest phenotype found among sensitive isolates.

The evidence suggests that the resistant isolates are a clone with a single origin, resistance having emerged in the commonest virulence phenotype prevalent at the time. In the course of genetic studies, the phenylamide-resistant pathotype was shown to be heterozygous for avirulence to R11 ($A_{11}a_{11}$), which has relevance for the control procedures being advocated.

Studies with two representative resistant isolates from different locations revealed complete cross-resistance to related phenylamide fungicides. At the highest concentration tested (100 μg per milliliter), cyprofuram was markedly phytotoxic and sporulation of resistant isolates was inhibited by approximately 30%, compared with the controls. It is unclear whether this reflects a genuine residual activity of this chemical against the resistant isolates, as has sometimes been noted with other fungi (10,37,46,47,49,59).

All resistant and sensitive isolates showed identical responses to the unrelated systemic fungicides propamocarb and fosetyl Al. The ED_{50} value for both fungicides was >10 to <100 μg per milliliter, with propamocarb being the more active.

During the course of these studies, a useful mutant form of *B. lactucae* became available; the mutant isolate had large lipid inclusion bodies within its condiosporangia that were clearly visible with the light microscope (55). The mutation did not appear to affect the pathogenic competence of fungal isolates carrying it, and they could be used as marked standard strains by which to compare the relative fitness of other isolates. Conidiosporangia of isolates to be tested were mixed in a 1:1 ratio with spores of a mutant isolate and were repeatedly cultured for three successive asexual generations on the universally susceptible cultivar Cobham Green. After each generation, the proportion of spores in the harvested population that carried inclusions was recorded. The extent to which test isolates predominated over the marked isolate or were themselves dominated provided a relative measure of fitness under the laboratory conditions of the test.

Tests were conducted using several metalaxyl-resistant field isolates, metalaxyl-sensitive isolates from either the field or the laboratory culture collection, and several sexual progeny isolates. Field isolates and isolates from the culture collection predominated in the mixtures with marked mutant isolates, and there were no indications that metalaxyl-resistant isolates were in any way less fit than metalaxyl-sensitive isolates. Some sexual progeny isolates did decline in frequency relative to the mutant isolate and therefore apparently lacked fitness. However, sexual progeny isolates with resistant, sensitive, or intermediate reactions to metalaxyl behaved in this way.

Genetics of phenylamide resistance

The segregation of response to metalaxyl was studied in progeny from crosses involving two metalaxyl-resistant isolates obtained from different sites and two different metalaxyl-sensitive isolates. F_1 (three crosses), F_2 (one cross), BC_1 (six crosses), and BC_2 (one cross) generations were investigated, and a total of 182 sexual progeny derived from oospores were evaluated for fungicide sensitivity and, in most cases, for specific virulence and SCT.

In the F_1 generation of crosses between resistant and sensitive parents, most progeny isolates recovered (56 of 65) expressed a phenotypic response to metalaxyl that was distinct from that of either parent. These isolates sporulated on seedlings grown in the presence of 0.1–100 μg per milliliter of metalaxyl, as did the resistant parent. However, sporulation took twice as long to occur as on untreated seedlings and on treated seedlings

inoculated with the fully resistant parent, i.e., 10–14 days compared with 5–7 days. This phenomenon was quantified in terms of the mean reciprocal latent period (time in days from inoculation to sporulation) for a batch of seedlings expressed as a percentage of this value calculated for the untreated control. Sensitive isolates had values of 0% at all concentrations ≥ 0.1 μg per milliliter, resistant isolates had values ≥95% over the same concentrations, and intermediate isolates recovered at F_1 (and subsequently at later generations) had values ranging from 20 to 80%, with the vast majority having values ranging from 50 to 60%. The remaining isolates recovered in the F_1 generation (nine of 65) were sensitive; this phenomenon is discussed later.

Progeny from backcrosses of intermediate isolates with the sensitive parents segregated 18 sensitive and 19 intermediate phenotypes, almost a 1:1 ratio. Intermediate isolates backcrossed to the resistant parents, however, yielded progeny of all three phenotypes—six resistant, 20 intermediate, and seven sensitive. When a sensitive F_1 progeny was backcrossed to a resistant parent, the cross yielded 10 sensitive and nine intermediate progeny. It proved more difficult to recover progeny from crosses between intermediate F_1 isolates (i.e., the F_2 generation) and crosses between resistant BC_1 progeny and the sensitive parent (i.e., the BC_2 generation), probably owing to inbreeding depression. However, one cross of the latter type yielded one resistant and 13 intermediate progeny isolates, and one cross of the former type yielded five intermediate and nine sensitive progeny isolates.

When considered together, these data indicate that sensitivity to metalaxyl is probably determined by a single locus showing incomplete dominance. The intermediate phenotype is considered to result from heterozygosity. Aberrant segregation ratios, particularly the occurrence of sensitive progeny in crosses involving the resistant parent, could result from induced selfing. However, this is unlikely to occur at as high a frequency as these data indicate (54). It is more probable that the resistant parent isolates were heterokaryotic and carried nuclei with at least one sensitive allele.

Further evidence of this heterokaryosis was obtained from experiments in which resistant isolates were maintained in the absence of metalaxyl for 30 asexual generations or more. Over this time, periodic assessment of fungicide sensitivity revealed a tendency for the response of these isolates to "drift" and approach that of the intermediate isolates. This did not occur when the same isolates were maintained in the presence of metalaxyl or when a resistant BC_1 sexual progeny isolate (presumed to be homokaryotic) was maintained in the absence of metalaxyl.

There was no evidence for an association between the locus for metalaxyl resistance and any loci controlling specific virulence, but this would probably have been difficult to detect given the relatively low number of progeny examined. Recombinant isolates carrying virulence for R11 ($a_{11}a_{11}$), which was lacking in the metalaxyl-resistant field pathotype, and the metalaxyl-resistant allele in the heterozygous condition (*Pp*), i.e., an intermediate phenotype, were recovered. This indicated no barrier to the emergence of a high level of metalaxyl resistance in isolates carrying virulence for R11.

Segregation of SCT was aberrant in some crosses, particularly in the BC_2 generation, which yielded all B2 progeny. Six homothallic isolates (five of which expressed an intermediate phenotype) were also recovered—the first time this has been observed in crosses between heterothallic isolates of *B. lactucae* (54,56).

Control strategy

A common response to control failure due to fungicide resistance has been to suspend recommendation of the product concerned and discourage its use. This is done in the hope that resistant variants of the pathogen will decline in frequency sufficiently to allow the fungicide to be reintroduced at a future date. The apparent lack of any fitness deficit in the phenylamide-resistant pathotype of *B. lactucae*, together with other considerations, has resulted in the adoption of an alternative and unique control strategy.

The phenylamide-resistant pathotype was shown to be invariably avirulent on R11, R16, R17, and R18 and to be of B2 SCT. R11 is carried by some commercially important butterhead lettuce cultivars for both protected and field cropping, although at present R16, R17, and R18 are not located in commercially useful cultivars. Hence, the use of cultivars carrying R11 effectively controls the phenylamide-resistant pathotype. Unfortunately, at the moment there are no commercially valuable crisphead cultivars carrying R11, although these are likely to emerge soon from breeding programs.

Virulence to match R11 has been known to occur in the British *B. lactucae* population for some years (22) but has been relatively infrequent. All isolates carrying virulence for R11 are, of course, phenylamide-sensitive. At present, therefore, a practical control procedure of growing cultivars carrying R11 but continuing to treat them with metalaxyl is being advocated to good effect. Because most isolates carrying virulence for R11 also lack virulence for R6 or R3, additional benefit is obtained from growing cultivars carrying R6 + R11 or R3 + R11. Such combinations are available in commercially acceptable cultivars. This strategy will function effectively only as long as virulence for R11 does not become combined in the fungus with phenylamide resistance. Further advice can be offered to minimize this eventuality, which laboratory studies have shown to be a possibility.

There are three ways in which virulence for R11 may become combined with phenylamide resistance. First, a new mutational event to fungicide resistance may occur in a genotype carrying virulence for R11. The probability of this occurring should be lower than for the original outbreak of resistance—which followed 5 years (from 1978 to 1983) of intensive metalaxyl use—because pure metalaxyl should no longer be in use. There should also be a greater consciousness of risk, together with increased use of alternative fungicides (e.g., zineb and fosetyl Al), and a greater likelihood that advice on cultural practices that minimize the chances of disease will be needed.

Second, mutation or asexual recombination in the present phenylamide-resistant pathotype may produce homozygous virulence ($a_{11}a_{11}$) for R11. It is known that the present resistant pathotype is heterozygous ($A_{11}a_{11}$) at the locus for avirulence to R11. An R11 virulent variant is most likely to be selected where cultivars lacking R11 are heavily infected by the phenylamide-resistant pathotype and are growing in proximity to R11-carrying cultivars. This would maximize selection for any variant carrying virulence for R11. Growers are therefore being strongly advised to avoid this situation.

Third, sexual recombination could result in the combination of virulence for R11 and phenylamide resistance. For this to occur, however, several conditions need to be met. A phenylamide-sensitive B1 isolate with virulence for R11 must mate with the B2 phenylamide-resistant pathotype. This can only occur on a lettuce cultivar lacking R11 and untreated with a phenylamide fungicide. Thus, all untreated lettuce lacking R11 represents a liability. One sexual generation would not restore a high level of phenylamide resistance, as the F_1 heterozygote would be intermediate. Two sexual generations are required, although the conditions allowing the second generation are less stringent.

If phenylamide fungicide usage is stopped in the presence of resistance, sensitive isolates can reappear, the fungus population becomes more mixed, and there is more opportunity for sexual recombination, perennation, and perpetuation of the problem. If fungicide usage is continued even in the presence of the resistant pathotype, however, all sensitive components of the population are still controlled, only the resistant pathotype needs to be controlled by other methods (e.g., resistant cultivars), and the risks of recombination and perennation are reduced.

An essential component of this approach to integrated

control is continuous monitoring of the fungus population. Work is now concentrating particularly on testing the fungicide sensitivity of isolates recovered from cultivars carrying R11, to provide an early warning of the occurrence of any recombination.

Discussion

The emergence and rapid distribution of the phenylamide-resistant pathotype of *B. lactucae* in the United Kingdom serves to illustrate how, under intense selection, a variant can come to dominate the population of asexually reproducing, aerially dispersed pathogens. This circumstance has demonstrated that the whole of the United Kingdom can be considered as a single epidemiologic unit with respect to a disease like lettuce downy mildew. There is good circumstantial evidence that rapid dissemination of the phenylamide-resistant pathotype has been assisted by the activities of specialist plant raisers who sell and transport lettuce plants between production areas.

The integrated control procedure currently being practiced is probably unique but does provide guidance to how other fungicide-resistance problems might be controlled. The use of cultivar resistance in combination with fungicides is no different in principle from the use of fungicide mixtures, frequently advocated as a means of combating resistance problems (31,32,34,66). Before the advent of phenylamide resistance in *B. lactucae*, integration with disease resistance had been suggested to avoid such an eventuality (21). Indeed, the unplanned use of cultivars carrying R11 in combination with metalaxyl, both of which were introduced to commerce at about the same time, may partially explain why the frequency of virulence to match R11 tended to be low for so long and why phenylamide resistance in *B. lactucae* took 5 years to emerge (21), in sharp contrast to some other related fungi (18,30,33, 38,45,58,61).

That phenylamide resistance appears to be regulated by a single locus showing incomplete dominance is consistent with suggestions that resistance is caused by a failure of the fungicide to bind to a modified form of the enzyme RNA polymerase (28,29,35–37,48). Homozygous resistant isolates with two functional alleles might be expected to grow and reproduce faster in the presence of the fungicide than heterozygous isolates with only a single functional allele. It is interesting that supposed heterozygous isolates did not respond to doses of metalaxyl above 0.1 μg per milliliter. This suggests that at the lowest concentration providing maximum inhibition, i.e., about 0.1 μg per milliliter, all sensitive RNA polymerase was inactivated, leaving the functional enzyme encoded by the resistance allele to sustain fungal growth and development, albeit slowly. Under these circumstances, increases in fungicide dose above the minimum required to inactivate all copies of the sensitive enzyme would not be expected to exert any effect, and this is what was observed.

Different levels of resistance to phenylamide fungicides have been reported in both laboratory and field isolates of a number of species. This may be due to the existence of different alleles for resistance but could also reflect the occurrence of genotypes heterozygous at the phenylamide-resistance locus or heterokaryons comprising nuclei carrying sensitive and resistant alleles. If the mutation to fungicide resistance occurs in a vegetative nucleus in nonzoosporic oomycetes such as *B. lactucae*, persistent heterokaryosis is an inevitable consequence until the fungus undergoes sexual reproduction. In zoosporic species, in contrast, a heterokaryon is likely to be less persistent, as homokaryons segregate from it.

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Salute to APS Sustaining Associates

This section is designed to help APS members understand more about APS Sustaining Associates. Information was supplied by company representatives. Each month different companies will be featured. A complete listing appears in each issue of *Phytopathology*.

Petoseed Co., Inc., Contact: Charlie Massie, Senior Vice-President/Sales, P.O. Box 4206, Saticoy, CA 93004. Petoseed was formed in 1950, specializing in research and production of hybrid vegetable seed. Petoseed currently breeds, produces, and markets 20 classes of hybrid and open pollinated vegetable seeds. Seeds are produced and sold both nationally and internationally. Petoseed has six research stations in the United States and seven testing locations under their direction internationally. The company is a pioneer in breeding for multiple disease resistance and the research department is currently working with over 80 different disease-causing organisms in their hybrid program. The major research thrust is to develop hybrid vegetables for specific market needs worldwide.

Pfizer Inc., Chemical Division, 235 E. 42nd St., New York, NY 10017; 212/573-3818.

Pioneer Hi-Bred Int'l, Inc., Contact: Steve Moon, Research Information Manager, 6800 Pioneer Pkway., Johnston, IA 50131; 515/270-4193. Pioneer was founded in 1926 by Henry A. Wallace and was the first company established exclusively to develop hybrid seed corn. Today, Pioneer maintains the largest private plant-breeding organization in the world with research programs in corn, soybeans, wheat, sorghum, alfalfa, and sunflowers. The company also markets bacterial inoculants for forage crops and livestock. Pioneer has research and marketing programs in the United States, Canada, and 60 countries overseas.

Rhone-Poulenc Inc., Contact: Richard K. Hanrahan, Fungicide Product Specialist, P.O. Box 125, Monmouth Junction, NJ 08852; 201/297-0100 ext. 3541. Rhone-Poulenc Inc. is a rapidly growing company engaged in the manufacturing and marketing of crop protection chemicals. It is the United States affiliate of Rhone-Poulenc S.A., the largest chemical manufacturer in France and among the 10 largest chemical groups in the world. Current products include fungicides (Aliette, Rovral, Chipco 26019) and nematicides/insecticides (Mocap, Zolone) for use on such crops as corn, grapes, almonds, stone fruits, lettuce, onions, peanuts, turf, and ornamentals. Aliette is a systemic material capable of providing both upward and downward translocation in the plant. It is active primarily against Phycomycetes (downy mildew, *Phytophthora*, and *Pythium* species). Rovral (Chipco 26019) is a broad spectrum fungicide providing excellent and long-lasting control of *Alternaria, Botrytis, Helminthosporium, Monilinia, Rhizoctonia, Sclerotinia*, etc.

Rohm and Haas Company, Contact: Dr. H. E. Carley, Fungicide Product Development Manager, Independence Mall West, Philadelphia, PA 19105; 215/592-6731. Rohm and Haas has been involved with agricultural chemicals since 1929, when it introduced Lethane, the first synthetic organic insecticide. In the 1940s, it developed Dithane fungicide, the most widely used organic agricultural fungicide in the world. Dithane fungicides (maneb and mancozeb formulations) are used to control over 50 fungal diseases on more than 80 crops. Its current research effort is concentrated on systemic sterol inhibitor fungicides.

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