HERBICIDES AND WORLD-WIDE DEVELOPMENT

By K. BRIDGE, Amchem Products, Ambler, Pennsylvania

The development of a compound as a herbicide in a variety of countries and climates is a complex business at best, and as for all agricultural chemicals a great deal of co-operation is needed. As it is usually better to begin at the beginning perhaps a brief outline of how such compounds reach the development stage would be useful.

The first prerequisite of any company, or for that matter any research organisation, interested in the discovery and development of newer and better herbicides is an ample and continual supply of new compounds. The agricultural division of Amchem is rather unique in that the organisation is aimed solely at the discovery, development, formulation, and sales of herbicides and growth regulators. It is possible, therefore, for us to enter into agreements with companies who have a regular supply of new compounds, and such compounds are screened in a such a manner as to evaluate all possible spheres of activity.

As new compounds are received, or synthesised by our chemists, cards are prepared showing the structural formula, the name of the compounds according to the American Chemical Association system, the empirical formula, and a filing system, which has been developed, makes it possible to check whether the compound has previously been tested. A suitable solvent or formulation is then determined and samples are made up by formulating 200 mg in 10 cc's for pre-emergence testing and 100 mg in 10 cc's for post-emergence. These dilutions are the equivalent to 16 and 8 lb a.i. per acre in 100 gallons.

The samples are applied to flats containing 16 selected weeds and crops and main observations are made two and a half to three weeks after pre-emergence application and seven to 10 days after post-emergence application, further observations being made as dictated from the effects of the treatments.

The results of this primary screening are assessed by a lab.-greenhouse committee, and in order that such findings are immediately considered for overseas development a member of our international division is included in this committee. The compounds are reviewed and either are dropped from further tests or are re-run on primary screening flats or are recommended for secondary screening. These categories are standard at the present time, though, for example, the weeds chosen for perennial screening may and in fact do change from time to time at the advice of our specialists and regional development personnel, usually at the time of one of the periodic development meetings held in Ambler. Perennial weeds which are screened over at the present time include Bermuda grass (*Cynodon dactylon*), quackgrass (*Agropyron repens*), Canada thistle (*Cirsium arvense*), field bindweed (*Convolvulus arvensis*), *Artemesia vulgaris,* and nut grass (*Carex* spp.). An effort is being made now to include problem weeds from various parts of the world, and this highlights the difficulties in propagation of some species and particularly the usefulness of such information from the supply source of the weed involved.

There is no set pattern followed with regard to the stage at which a compound is given to colleges and State and Federal research stations. This is based on the activity and selectivity of the compound and to a certain degree on the availability. Some compounds may go out to research workers almost immediately after primary screening if particular selectivity has been recorded, while others may go through various stages of secondary screening on the farm before being sent to outside research agencies. Again the time of the year has some bearing on the follow-up programme and a compound which has passed through primary screening late in the spring, and which has shown high activity, may well go into field tests immediately.

Over the last few years a number of compounds have passed through the normal screening procedure and eventually were sent overseas to be evaluated in specific crops and situations. Of these a number have been tested in New Zealand and Australia, both by Government research personnel and by associated companies. Similar investigations have been undertaken in Europe and Latin America and in parts of the Far East.

Perhaps the most interesting single compound of those developed by Amchem, and one which is still being developed in many areas of the world, is amitrole. Its herbicidal properties were discovered some years ago and its activity particularly against perennial weeds was considered an unusual feature. A good deal of the earlier work, both in the United States and Europe, was carried out with quackgrass where a preplanting technique was evolved, and arising from this early work studies were soon under way to investigate the activity of amitrole when combined with ammonium thiocyanate. Work by Fertig at Cornell, Raleigh at Penn State, Buchholtz of Wisconsin, Frank at Ontario, and from a number of European research centres has shown that in most cases 4 lb a.i. of amitrole when combined with a little under 4 lb of ammonium thiocyanate will give approximately double the control of quackgrass, compared with 4 lb of amitrole alone. At the present time investigations based on the original work are being carried out in such problems as kikuyu grass (*Pennisetum clandestinum*) in small grain cereals in such countries as Colombia and Ecuador, where to date at least one cleaning crop has been necessary to avoid reinfestation, which makes direct reseeding, or the growing of a grain crop, impractical. Work also continues in Europe, South America, and other countries to evaluate and develop the new amitrole formulation under many permanent crops such as grape vines, coffee, citrus, apples, and rubber.

The Rubber Research Institute of Malaya in recent work have found that the most effective compound for the control of *Paspalum conjugatum* is amitrole, but this institute has not investigated the ammonium thiocyanate combinations too well as yet. *Paspalum conjugatum* is a dominant grass in both young and mature rubber areas, usually along with *Axonopus compressus,* and where the two are in association a mixture of dalapon and amitrole is recommended. Five lb a.i. of amitrole and 5 lb of dalapon a.i. in 100 gallons water per acre are the actual recommendations.

Nearer to home an interesting report is published by the research committee of the Western Weed Control Conference referring to the importance of timing of amitrole applications for the control of salmonberry (*Rubus spectabilis*). This report by Sinclair and Amen records a series of tests put out in 1959 on the Oregon Coast to determine if control could be improved by timing applications. One, two, and four lb a.i. of amitrole were used and three different dates of application, namely 26 May, 28 July, and 23 October, corresponding to spring, mid-summer, and fall. Observations made during 1960 showed that mid-summer applications were much more effective than the earlier or later applications, there being approximately 25 per cent regrowth in plots treated at the 2 lb a.i. rate and less than 10 per cent regrowth at the 4 lb a.i. rate.

An interesting study has been carried out over the last two years with formulations of amitrole for the control of water hyacinth (*Eichhornia crassipes*) by the Crops Research Division of the Agricultural Research Service and these studies are being duplicated in the Sudan where this weed is a problem of prime importance. Seaman reported at the Southern Weed Control Conference this year that Weedazol TL, a formulation containing 2 lb a.i. of amitrole and 2 lb of ammonium thiocyanate per gallon, gave over 90 per cent control of water hyacinth at rates of 1.5 to 2.0 lb a.i. per acre with respect to amitrole, when applied in water at 100 gallons per acre. When applied at 200 gallons per acre this formulation gave over 90 per cent control at rates of 0.5, 1.0, 1.5, and 2.0 lb a.i. per acre. Comparing these results in the same test with an amine formulation of 2,4-D, only 45 per cent control was obtained at 6 lb a.i. per acre in 100 gallons per acre, but 83 per cent control was obtained after treatment with 6 lb a.i. in 200 gallons per acre. Correspondingly less control was achieved at lower rates with either volume. The maximum effects of amitrole/ammonium thiocyanate mixture took about four weeks longer to develop than did those of 2,4-D, but regrowth of vegetative offshoots (daughter plants) and consequent loss of control were less in the plots treated with the mixture than with 2,4-D.

The relatively poor control given by 2,4-D was thought to be related to its poor transport through the stolons from parent plants to attached offshoots. Since amitrole has been shown to be more mobile than 2,4-D in other plants probably the superior translocation of amitrole/ammonium thiocyanate may explain its superior control through effective repression of offshoot regrowth. The better control obtained at the high gallonages is probaby due to a more efficient coverage with more offshoots contacted by the spray solution. These offshoots were protected by the mature foliage of the dense stands of weeds in this series of experiments. These experiments are being repeated on a much larger scale this year in the United States, as it looks as if the mixture can be developed as an alternative herbicide to 2,4-D for the control of water hyacinth, the economics being particularly attractive.

In New Zealand, as in many other countries, there has been, of course, a great deal of interest in the development of total vegetation mixtures of herbicides and amitrole has played an increasingly important role in this field. An interesting feature of this research as a whole is the many different combinations which have been developed, showing so clearly that a given mixture ideal for one set of conditions is not necessarily optimum for a different area. In Europe, and particularly France and Germany, weed control in such situations as railroad tracks and the like has been studied for a number of years. I think we all appreciate the difficulties encountered in this type of work. There are no crops to compete with the weeds, no ploughing and cultivations to help, no useful rotations, and often we find that a weed we have relatively little trouble with in a field of wheat becomes extremely difficult to kill when growing in track ballast. At a recent meeting of the overseas licensees of Amchem in Paris a considerable amount of data was presented and it will not be possible to present this in the time at my disposal. Briefly, in the United States we have found that 4 lb a.i. of amitrole and 16 lb a.i. of monuron or 10 lb a.i. of simazine gives a good knockdown of a variety of annual and perennial weeds and at the same time gives a residual effect sufficient to give seasonal control. In France after working with mixtures of amitrole, TCA, and 2,4-D the need for a combination giving more permanent control was realised and experiments were soon under way with mixtures of amitrole, monuron, diuron, and simazine. At the present time a combination is now being marketed containing 10 per cent of amitrole, 30 per cent of simazine, and 60 per cent 2,4-D amide. In Germany the pattern of development has been much the same and amitrole is used in combination with the triazine compounds using varying ratios to meet particular situations.

This has been the general picture of the development of amitrole, but I have not mentioned the work in bracken (*Pteridium aquilinum*) and a number of brush species where amitrole is finding a place in a variety of countries. It is my intention only to try and outline a few of the areas where this very useful material has been used.

AMIBEN

The development of the pre-emergence herbicide amiben followed its synthesis in Amchem's laboratories after the activity of its sister compound dinoben was first studied. The amino substitution showed more selectivity over soybeans, giving less formative effects, and in the United States during the early stages of its development the emphasis was placed mainly on work in soybeans, as there was a considerable need for an efficient pre-emergence herbicide in this crop. The increase in popularity of solid planting has made it even more necessary to find a complete answer to the weed problems in this crop and has tended to increase extension work with amiben. A label has now been approved by the U.S.D.A. for soybeans grown for seed, this pending the completion of the residue and toxicity studies which are now well advanced. While the compound has been evaluated in the United States in a very wide variety of crops, amiben has been developed very rapidly indeed on crops other than soybeans in Europe and some quite novel uses have been found. Carrots have a considerable tolerance to the compound and rates of 3 to 4 lb a.i. per acre in Italy satisfactorily controlled *Setaria* spp., *Digitaria sanguinalis, Stellaria media, Portulaca oleracea, Lamium purpureum, Amaranthus retroflexus, Chenopodium album,* and *Polygonum aviculare*. Other European countries have confirmed these results and amiben will become a commercially acceptable herbicide in carrots very soon. The liquid formulation of amiben is also being actively developed in many varieties of beans, such as limas, kidney, and other bush types, and there is considerable interest in Latin America in this respect. At rates about 3 to 4 lb a.i. per acre satisfactory weed control is possible and with the exception of a very few varieties no formative effects or other undesirable features have been seen at these rates.

Some of the early work showed that it would also be possible to use a granular formulation in transplant crops such as the brassicas and tomatoes. Cauliflower and Brussels sprouts have shown a good tolerance and in general excellent weed control can be obtained by an application of the granular amiben after transplanting at rates of 4 lb a.i. and above. The granular material is formulated on a 24/48 mesh attaclay and contains 10 per cent of the active ingredient.

A comprehensive trial made in France last year indicated that sugar beet is remarkably resistant to a post-emergence application of granular amiben. The application was made after thinning and, of course, normally the rows are hoed clean during the thinning operation. The results in terms of weed control and harvest yield were excellent and compared very favourably with plots that had been hand-weeded three times between thinning and harvest. This investigation is being widely increased this year all over Europe and also in the United States, and as sugar beet is sensitive to pre-emergence sprays of amiben it is possible that it would be worth while to look at a programme involving pre-emergence applications of chlorpropham or endothal, following this with a post-thinning application of granular amiben.

Barnyard grass (*Echinochloa crusgalli*), a persistent and difficult weed in rice, can be controlled with a pre-emergence application of liquid amiben at rates of about 3 lb a.i. per acre, the application being made pre-emergence to the weed and before flooding is carried out. Tests are currently under way in Italy, Japan, and South America to evaluate amiben in combination with other herbicides to try and increase the effective control of this weed in rice.

In peanuts a useful combination of amiben and dinoseb has been experimented with, the application being made just after the crop has germinated and up until the time the peanuts are in the crook stage. One-and-a-half pounds a.i. of amiben has given sufficient residual control of germinating weed seeds and one-and-a-half pounds of dinitro is taking out the young weed seedlings present at this stage of the crop.

Similar to most pre-emergence compounds amiben requires adequate soil moisture conditions and a reasonable soil texture in order that the chemical can penetrate to the root zone of the germinating seed. With ½ to 1 in. of rain the first ten days to two weeks after treatment 4 lb a.i. per acre has given consistently long-lasting excellent control of annual broad leaf and grassy weeds. Under drought conditions even higher rates have been generally disappointing.

FENAC

The initial use of fenac to weed control investigations in the United States during 1958-1959 was that of a slow-acting perennial weedkiller and the main interest centred round bindweed (*Convolvulus arvensis*).

At rates of 10 lb a.i. per acre and above this weed was eradicated. Results of further work, however, showed considerable variability and obviously soil type, moisture, and temperature all affect the apparent toxic level in the soil, both during the control period and the following crop season.

While there does remain considerable interest in the use of fenac for the control of perennial weeds, its current application seems to lie in the area of annual weed control.

In sugar cane particularly a great deal of development work has been carried out and in the United States this year a label has been approved for the use of fenac in plant cane used for seed.

Dr Ernest Stamper, of Louisiana State University, has been almost entirely responsible for the early work carried out in cane in the United States and at the 1961 Southern Weed Control Conference he reported on his work and presented considerable yield and weed control data. The application in the United States has been made at rates of from 2 to 3 lb a.i. per acre of fenac on the drill in plant cane and good control of weeds, both broad-leafed and grassy, was obtained for several months.

Results from Peru and other South American countries and from Puerto Rico indicate that weed control can be obtained with an overall application of 3 lb a.i. of fenac per acre applied at the time the cane is planted.

Further work in the United States has shown that fenac is probably the only compound known at the moment which will adequately control the parasitic weed *Striga asiatica.* Though no findings have been published a U.S.D.A. work project group in North and South Carolina have compiled considerable data. In the two years the programme has been under way, fenac as a sodium salt has consistently produced *Striga* control in maize in the realm of 90 per cent or better at a rate or 4 lb a.i. per acre. Soil incorporation appears to be essential and the application is made after ploughing, but before the final seedbed cultivations are made. Unfortunately, tobacco is traditionally grown after maize in this part of the United States, and as there is sufficient fenac left in the soil to hurt the following tobacco crop, some changes in rotations have been made. Attempts are currently being made to evaluate this material in other areas of the world such as Africa and India where *Striga* species are a problem in crops such as maize, sorghum, and sugar cane.

As fenac has a very considerable soil residual, there has been an interest in its use in total vegetation control mixtures, and in France its addition to amitrole and simazine mixtures often has given encouraging results. In the west of the United States combinations of fenac, amitrole, and simazine at 3, 2, and 3 lb a.i. per acre respectively have controlled wild oats, cheat grass (*Bromus* sp.), annual blue grass (*Poa annua*), *Filaria* (*Erodium* spp.), yellow star thistle (*Centurea solstitialis*), tumbling mustard (*Sisymbrium altissimum*), and pigweed (*Amaranthus* sp.). Kochia was also controlled whenever fenac was applied.

Possibly the most interesting of the more recent development work carried out in Europe is the use of fenac in mixture with other herbicides in small grain cereals. From a small greenhouse trial in Ambler, Pa., in 1958, to a small field trial in France in 1959, and several field trials in Sweden and Switzerland in 1960, a stage has now been reached which has provoked wide scale testing this year. Mixtures of ¼ to ½ lb a.i. of fenac plus ¾ to 1 lb a.i. of MCPA per acre have given good control of the hard-to-kill weeds including *Polygonum* spp. and *Galium aparine* with no evidence of damage to the cereals. Mixtures of fenac and MCPP and mixtures of all three have also given some very encouraging results. Data will be compiled from several European countries this year to check the timing of the sprays, varietal sensitivity, and the optimum rates needed.

To cover all the development projects we have scattered round the world would be an impossible task in one paper and I have deliberately omitted the very considerable amount of work which is being carried out by our New Zealand and Australian associates and by the many Governmental agencies in these two countries. I am very much indebted to the people working in New Zealand on some of our newer growth regulators, in peaches and other orchard crops, a field incidentally with much promise and one in which Amchem is vitally interested. I have also not been able in the time allotted to discuss the great interest in this part of the world in the invert of water in oil emulsions, and the work carried out in England and Scotland with these for bracken control. The application of such materials by special as well as standard equipment is also a study of great importance, which is being actively pursued not only in the United States, where the invert is really coming into its own for the control of woody plants on rights-of-way and in forestry situations, but also in Europe and Australasia. I feel sure that the weed problems of New Zealand will be very thoroughly covered during this meeting and I hope that this brief resume of how some of these problems are being tackled on a world-wide scale has been of some help.

I said at the beginning much co-operation is essential before such a development programme can be even envisaged. I have found that weed workers, whether they be in Brazil or Japan or any other country, are always ready to give this co-operation and for this I am truly and sincerely grateful.