HERBICIDES AND THE AMERICAN FARMER

by

R. H. BEATTY

(Director of Research, Agricultural Chemicals Division, Amchem Products Inc., Ambler, Pa., U.S.A.)

Introduction

I have been asked to discuss some of the newest developments in American chemical weed control work and the way we are using herbicides in our truck crops. There are widely varying conditions in our country, and therefore differences in opinion among American weed workers, but this paper represents the opinion of the majority of these.

The American farmer uses 2,4-D on most of his grain crops, including oats and rice for which many research workers recommend MCPA. The main reason for this is cost, since several American chemical companies are basic in phenol and 2,4-D is made in very large quantities and at a much lower cost than MCPA. In fact, most of the MCPA we use is imported. MCPA is used for weed control in flax and would find a greater market for rice on the West Coast if the difference in cost were not so great. Unfortunately, some of our farmers do not always use the recommended herbicide, but decide on the basis of price per gallon, rather than cost per acre or expected crop yield.

Herbicides in America

It is estimated that in the United States the cost of farm labour has increased 400% during the past 25 years but, even so, there are fewer and fewer men available for farm work. Because of this and other production expenses, the farmer's profit margin has become smaller and the need for greater efficiency increasingly urgent.

The small family-operated farm in America is rapidly disappearing. To meet competition, farms have been consolidated into larger units permitting the use of mechanised equipment, which is essential to the big business most farming has now become. Chemical weed control has helped considerably in solving the problems of labour shortage and increased costs. The labour requirements of the Mississippi cotton grower for mechanical weed control range from 20 to 41 man-hours per acre, but the use of herbicides in cotton reduced this to about 5 man-hours per acre, and also increased yields somewhat, leading to an average gain of $21 per acre. The gains from controlling weeds chemically in rice are even very much greater, running as high as $400 per acre in foundation stock commanding a premium price as seed.

The American livestock farmer has learned that spraying kills more weeds than does mowing. In terms of grazing, the increased profit after spraying pastures may be twice that obtained after mowing. We have vast areas of rangeland infested with, or being invaded by, woody and perennial herbaceous weeds. In Oregon, controlling big sagebrush (*Artemisia tridentata*) with herbicides costing $2·25–3·25 per acre has given a net gain estimated at $1·68 an acre. Dr. W. B. Ennis, who administers the United States Department of Agriculture crops protection research, pointed out that 'if such a treatment were applied on one-fourth of the 96 million acres of range infested with big sagebrush, an annual gain of over 40 million dollars might be realised—control would be effective to some degree for at least 10 years; thus the gain would be about 10 times as great as the figure indicated'.[1] In addition, on such huge areas spraying is often the only really practical way to control encroaching vegetation which can reduce the value of the land to the point where 10 acres are required to carry a single steer.

Biological aspects of weed control

The biological aspects of weed control are also becoming increasingly complex. As our world shrinks and we constantly have more contact with each other, many barriers fall and the boundaries of weed populations are no exception. The most recent example of this is witchweed (*Striga asiatica*), a serious parasitic plant which has jumped from the Old World tropics to attack maize, sugar cane, small grains and other grass and sedge species in South and North Carolina. American farmers must learn to control witchweed, just as they are learning to control halogeton (*Halogeton glomeratus*), Canada thistle (*Cirsium arvense*), bindweed (*Convolvulus arvensis*) and the others inevitably introduced and spread in spite of the most careful precautions.

Another type of biological change that complicates the chemical weed control situation is the way changes in weed population occur when ecological balances are upset. We are all familiar with the increase of grasses after broadleaf weeds have been controlled. This also has been found to occur among broadleaf weed species. In spinach fields, henbit (*Lamium amplexicaule*) infestation increased after we eliminated chickweed (*Stellaria media*). Then, after henbit was controlled, Virginia peppergrass (*Lepidium virginicum*) became a problem. We know that there is no end to other problems which can arise as the complex interrelated factors of agriculture are adjusted and readjusted.

The American farmer's acceptance of chemical weed control

We also know there is no substitute for good cultural practices, but the advantages of chemical weed control become apparent to more American farmers every year. We have now reached the point where more acres are sprayed for weed control than for the control of insects and diseases combined. Last year, this amounted to over 35,000,000 acres of farm land. Typical data from the state of North Dakota illustrates the rapidity of development; nearly three times as many acres of farm land were treated with chemicals for selective weed control in 1957 as in 1953. About 70% were treated by farmers with their own or borrowed equipment and about 30% by custom sprayers or operators.

These figures assure us that most progressive American farmers are definitely interested in and using herbicides, and this will increase as new chemicals and new techniques are introduced. Today, many mid-Western farmers are buying a new type six-row planter equipped with attachments for applying fertiliser, seed, soil insecticides and pre-emergence herbicide band treatment in one operation, all to reduce labour and ensure a satisfactory crop.

As K. P. Buchholtz (University of Wisconsin) pointed out realistically, we must look at weed control as part of the whole farm programme, not as an isolated practice related only to a specific crop. For instance, several farmers using a simazin pre-emergence spray on maize with good results this year, remarked that by being freed from cultivating, they were able to produce better hay. The cost of spraying does not have to be charged to one crop, but should be considered as part of the whole. The benefits can be indirect as well as direct.

The importance of vegetable crops in America

In the United States, in 1956 we grew about 5,000,000 acres of vegetables with a farm value over $1,500,000,000. Some vegetables are grown in every state, but the main supplies for fresh market come from California, Texas and the South Atlantic states. California and the North Central states of Wisconsin, Minnesota and Illinois lead in raising vegetables for processing. There is a decided difference in crop value, the average farm value of fresh market vegetables being $375 per acre compared with $150 per acre for those which are canned, frozen or dried.

Pre-emergence herbicide treatment

Most of the herbicides we are using on vegetables are applied pre-emergence to the weeds. Unfortunately, there are several rather rigid factors which determine the success or failure of pre-emergence treatment. The pre-emergence herbicide must be tolerated by the crop, and most of the chemicals used must be present in lethal concentrations in the region where the weed seeds are germinating.

The complexities of soil texture and colloidal properties, and physical characteristics of the chemical affect the concentration and distribution of the herbicide. The work of Warren (Purdue University) indicates that TCA and dalapon (2,2-dichloropropionic acid) are not held by the soil. The benzoics (2,3,6-trichlorobenzoic acid and related isomers) and CDAA (2-chloro-*NN*-diallyl-acetamide, sold as Randox) are attracted to some degree. CIPC, pentachlorophenol and certain substituted urea compounds are adsorbed in much larger quantities. Rates of chemical applied will therefore vary with different soil types.

Moisture content of the soil at planting time and rainfall following treatment affect concentration and distribution, and these two factors are the cause of erratic results with several chemicals. Overhead or furrow irrigation as practiced by many vegetable growers can help correct this factor. If the chemical is subject to rapid inactivation, then temperature, moisture, light and soil microbiological activity will affect its weed-killing properties.

older stage and the weeds are still small (under 3 in.) using the CIPC–Vegedex combination in either liquid or granular form. Post-emergence application of granular CIPC is being used commercially on lettuce. Often our farmers cut leafy crops two or three times during a season, cultivating and fertilising afterward each time. In such a system, these granular materials could extend the period of weed control considerably through treatment after each cutting.

Carrots, celery, parsnips and parsley

We, like you, use undiluted special light aromatic oils such as Stoddard solvent as the standard herbicides for carrots, celery, parsnips and parsley. Growers of these crops would rather have a herbicide that is less bulky, less expensive and longer lasting, and one that will control galinsoga (*Galinsoga ciliata*) and ragweed.

For carrots, two new experimental materials look very interesting because they are selective, have residual activity, can be applied with conventional low-volume equipment, and do not involve the expense of bulk. Pre-emergence application of 4 lb. of Dinoben/acre controls annual grasses and broadleaf weeds for 4–6 weeks. Preliminary tests of Niagara 4562 indicate promise as a post-emergence treatment: 2–4 lb./acre applied when the carrots were in the two-to-four-leaf stage controlled crabgrass, pigweed and lambsquarters.

Vegedex is being applied experimentally to transplanted celery before weeds emerge. Celery fields are irrigated immediately after transplanting, and application of 4–6 lb./acre is made over-all as soon as equipment can be used on the land after irrigation. Some leaf burn has occurred, but the treatment has not produced permanent injury. This treatment is actually post-emergence with regard to the crop and pre-emergence with regard to the weeds.

Onions

For years, sulphuric acid and potassium cyanate were used on muck-grown onions at emergence or after the flag stage, but their use is hazardous and can produce serious onion burning. Sulphuric acid is still used in some areas, but today, the most-used herbicides are CIPC and Randox, the choice depending on climatic and soil conditions and the weeds to be controlled. CIPC is used to control purslane (*Portulaca oleracea*) and smartweed on muck soils, and also annual grasses on mineral soils. On muck soils, Randox controls grasses better, and controls broadleaf weeds like lambsquarters, ragweed and redroot but not smartweed. With care, CIPC or Randox can be used as a directional post-emergence treatment.

Potatoes

Pre-emergence application of 3–6 lb. of DNBP/acre is generally used by potato growers in the Northeast. This is satisfactory when moisture conditions are good, but not if the soil is too wet or too dry. In the mid-West, herbicides are used very little, being limited primarily to emergency use of 2,4-D when bad weather has prevented the last cultivation before lay-by.

The biggest need for this crop is a herbicide for lay-by treatment. 2,4-D or sesone (sodium 2,4-dichlorophenoxyethyl sulphate) are occasionally used after lay-by, and granular formulations of these chemicals or EPTC may prove useful.

Other vegetable crops

Monuron, 3-(*p*-chlorophenyl)-1,1-dimethylurea, is the herbicide we use most widely for asparagus. Dinoben is also promising. At the end of the cutting season, amitrol (3-amino-1,2,4-triazine) has been used successfully for spot treatment of horsetail (*Equisetum arvense*), milkweed (*Asclepias* spp.), quackgrass (*Agropyron repens*) and Canada thistle. Dalapon has also been used in the same manner to control quackgrass.

Pre-emergence applications of TCA are used to control annual grasses in fields of canning beets in the mid-West. Sodium chloride is used on beets in some other sections, but is not very satisfactory. EPTC worked into the soil before planting is probably the most promising experimental control. Endothal (3,6-*endo*-oxohexahydrophthalic acid), recently approved by the U.S.D.A. for use on sugar beets, might also be helpful.

For cucumbers, muskmelons and watermelons, pre-emergence treatment with NPA (*N*-1-naphthylphthalamic acid, sold as Alanap 3) is generally recommended. Vegedex is being used somewhat on cucumbers, and Dinoben looks promising on pumpkins and squash.

New herbicide techniques and chemicals

Although the substituted phenoxyacetic acids—2,4-D, MCPA and 2,4,5-T—have contributed more to weed control in general than any other group of herbicides, they have been inadequate in several respects. Their chief weakness is lack of grass control, even as a pre-emergence treatment. Several perennial broadleaf weeds are not being killed to the farmer's satisfaction—Canada thistle, horsenettle (*Solanum carolinense*), whitetop (*Cardaria draba*) and bindweed, to name a few.

Today, farmers seeing the wonders of 2,4-D, MCP, Dinitros and other herbicides are asking for chemicals with greater selectivity, chemicals which will eradicate perennial weeds but permit planting crops, and pre-emergence chemicals which are more reliable. Our mid-West farmers want a post-emergence chemical to control wild oats in wheat; a post-emergence chemical for grass control in cotton is wanted by our southern farmers; our eastern growers would like to control yellow rocket (*Barbarea vulgaris*) in grain fields under-seeded with legumes and we have many, many more problems.

Dr. W. C. Shaw gave an excellent description of our American weed control organisation at the 1954 Weed Control Conference,[4] and this has not changed appreciably. Industry works closely with college and government workers and supports some of the fundamental studies through grants. In the United States, industry's main contribution, however, is synthesising and screening chemicals for biological activity, providing new weedkillers and encouraging the development of their potential.

Dalapon

Dalapon is definitely an improvement over the unreliable TCA for controlling Johnson (*Sorgum halepense*), Bermuda (*Cynodon dactylon*) and quackgrasses. Although its persistance in the soil is a disadvantage as far as many crops are concerned, maize, potatoes and beans can follow perennial grass treatment after a time interval determined by soil type, moisture and other factors. Recent results indicate that dalapon may be quite useful in controlling wild oats and seedling grasses in sugar beets, and it is approved by the U.S.D.A. for controlling annual grasses in flax. One lb. of dalapon/acre has given good control of grasses treated when small. Dalapon is also helping the farmer control grasses in apple, pear, apricot and peach orchards and quackgrass in asparagus plantings.

Mixing dalapon with 2,4-D, 2,4,5-T or amitrol gives a material that will remove most grasses and broadleaf weeds by foliar absorption and translocation into the roots. A combination of dalapon and 2,4-DB will remove annual grass and broadleaf weeds from seedling stands of lucerne and birdsfoot trefoil, a major contribution uniting the results of British and American research for the farmer.

Amitrol

The outstanding contribution of amitrol is its excellent control of Canada thistle, whitetop, horsetail, poison ivy, cattails (*Typha latifolia*) and other perennial broadleaf weeds. It is absorbed and translocated rapidly and its apparent persistence in the plant often produces delayed or prolonged reaction. For controlling Canada thistle, amitrol is most effective when applied to plants growing on undisturbed soil. Infestations should be sprayed soon after the emergence of as large a proportion of shoots as possible.

In our mid-West, farmers are spraying their Canada thistle, waiting 7–10 days (depending on temperature) and planting maize and soya-beans with no detrimental effect to the crop. Amitrol is being used to control Bermuda grass in citrus orchards, quackgrass and poison ivy in apple orchards and cattails in western irrigation ditches. Post-emergence application of amitrol has controlled annual grasses in corn and Canada thistle in oats without reducing crop yields.

Combinations of amitrol with TCA, the benzoics, simazin [2-chloro-4,6-bis(ethylamino)-*s*-triazine], dalapon and substituted urea compounds have produced interesting results. Unfortunately for brush control work, antagonism has resulted when amitrol has been combined with the present phenoxy formulations.

Amitrol $1\frac{1}{2}$ lb. plus 8 lb. of simazin, monuron, or diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] has given excellent total vegetation control, with residual action against invading annuals for one growing season. Where Bermuda and Johnson grass are the problem, the amitrol–

2,3,6- and the poly- (consisting of 2,5-di-, 2,3,5-, 2,3,6-, 2,4,5-tri-, 2,3,4,5- and 2,3,5,6-tetra- and the penta-) chlorobenzoic acid isomers were tried on field bindweed that their place in the herbicide field was realised.

Last year, two benzoic products were sold to the farmer for bindweed eradication competing with the high rates of chlorates generally used. One, containing primarily 2,3,6-trichlorobenzoic acid, is applied at 20 lb./acre. The other, containing the mixture just described, is applied at 40 lb./acre. Both benzoic materials cost the farmer the same on an acre basis.

Their effect on bindweed and quackgrass seems to be based primarily on absorption through the roots. These chemicals are absorbed through the foliage, translocate readily through the plant and are excreted from the root tip. Apparently they inhibit the regenerative properties of susceptible plants.

Low rates of 2,3,6-trichlorobenzoic acid applied as a foliage spray are quite effective in killing such woody plants as persimmon (*Diospyros virginiana*), locust (*Robinia pseudoacacia*) and certain evergreens such as balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*) which are quite resistant to the phenoxy acids. Other perennial broadleaf weeds controlled by the benzoics are leafy spurge (*Euphorbia esula*), Russian knapweed (*Centaurea repens*), bur-ragweed (*Franseria discolor*), trumpet vine (*Campsis radicans*) and Japanese bamboo (*Polygonum cuspidatum*), to name a few.

A major weakness of the benzoics from the farmer's viewpoint is the long residual toxicity, which interferes with crop rotation in many areas. Maize seems to be the crop most resistant to the 2,3,6-isomer. The response of other crops varies with substitutions on the ring.

Fenac

2,3,6-Trichlorophenylacetic acid (Fenac), introduced to certain research workers last year by Hooker Chemical Corp., provides a good example of a major development resulting from investigating ring substitutions. The acid and amide have long residual action against many annual weeds, and low rates are tolerated by maize and established turfgrasses. At rates as low as 3 lb./acre on our company farm, Fenac has controlled annual weeds and quackgrass for the entire growing season.

Co-operative research of my company with Dr. S. M. Raleigh (Pennsylvania State University) showed that Fenac at 2–6 lb./acre was the most effective of six herbicides tested for killing quackgrass. Maize grew normally when planted 7–10 days after treatment with 3 lb./acre, but was injured by higher rates. We are now investigating the possibility of avoiding crop injury by applying Fenac to quackgrass in the fall.

Hooker's results indicate that on bindweed Fenac is equal to, and often seems to be more effective than, 2,3,6-trichlorobenzoic acid: further work may show increased effectiveness against other perennial broadleaf weeds.

Dinoben and Amoben

We became interested in the selective properties of the benzoics and have developed two related pre-emergence chemicals with good crop selectivity which control a wide range of annual weeds. These materials are also the result of investigating ring substitutions.

Dinoben (3-nitro-2,5-dichlorobenzoic acid) is much more selective than the parent compound, 2,5-dichlorobenzoic acid. Asparagus, carrots, maize, lettuce, flax, peas, potatoes, squash and peppers tolerated a 4-lb./acre pre-emergence treatment which controlled annual grass and broadleaf weeds for 6 to 8 weeks.

Amoben (3-amino-2,5-dichlorobenzoic acid) seems to be a more effective herbicide and in addition to the crops just mentioned, shows greater tolerance by soya-beans. Amoben 4 lb. applied pre-emergence to the crop gave excellent seasonal control of annual broadleaf weeds and grasses without injuring soya-beans in tests at Ohio State University and on our company farm in Pennsylvania.

With brassica and tomato transplants, potatoes and squash, granular Amoben looks promising when applied before the weeds emerge.

Dinoben and Amoben have severely damaged snap beans, table beets and cucumbers. Effects of moisture, soil structure, temperature, light and other factors will be studied.

Invert emulsions

My company has been investigating inverted emulsions of the phenoxy acids, particularly as brushkiller formulations. We have also been working with inverted esters, oil-soluble amines and acids of the phenoxyacetic acids. When the formulations are mixed with oil and water in various proportions, a viscous material similar to buttermilk or mayonnaise is produced. In our research we have attempted to evaluate these new formulations with regard to drift characteristics, herbicidal activity and marking properties.

To study these factors in relation to viscosity of the material, a centrifugal sprayer was developed with which we could vary volume and droplet size, and distribute very viscous materials which cannot be sprayed from conventional equipment. It is too early to draw definite conclusions, but satisfactory results have been obtained with our new sprayer and the invert emulsions when applied by helicopter or fixed-wing aircraft. Seven gal. total volume per acre applied from a helicopter seems to be a good marker. When the material was applied from altitudes necessary to clear the steel towers which appear on rights-of-way, the material and sprayer reduced drift. We have applied the material satisfactorily at wind velocities well over the present 5 m.p.h. limit. With regard to herbicidal activity, the material appears to equal conventional sprays on most species, and is superior in translocating properties on mesquite. Control of several hard-to-wet water weeds, such as water lettuce (*Pistia stratiotes*), appears encouraging with this new formulation.

Conclusion

Hitherto as far as herbicides are concerned, the surface has hardly been scratched: we have solved a lot of problems, but we still have many more to solve.

American farmers have benefited tremendously from the remarkable co-operation between academic and industrial herbicide research groups, and also from co-operation between British and American research workers. We certainly expect this will continue and increase, to the advantage of all.

References

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Discussion

Dr. R. E. Slade.—I should be interested to know how the names of new herbicides are made in the U.S.A. MCPB is already sold under five different names in this country. It is very confusing for the farmer. We have official names for about ninety chemical substances, and nearly all of these names contain no vowels, e.g. CMPP, 2,4-D.

Mr. Beatty.—The Weed Society of America has a Nomenclature Committee which selects a common name for a chemical, such as amitrol for 3-amino-1,2,4-triazole. Industry can use any trade name they desire but it is to their advantage to have the common name appear on the label because the extension service and all publications refer to the common name and often the farmer will ask for the product by the common name.

Dr. W. Davies (Grassland Research Inst.).—In my experience dalapon is the first effective grass killer which at the same time does not unduly harm the clovers. If this is so, then we have available a first-class tool for controlling grass/clover ratios in pastures, as well as means for cleaning arable land of obnoxious weeds, e.g. couch and bent. Could Mr. Beatty say whether there is evidence in the U.S.A. to suggest that dalapon is selective among the grasses? My limited experience suggests that *Agrostis stolonifera* is more susceptible to dalapon than say *Phleum pratense*. The latter seems in fact to be considerably resistant. What is the North American experience in this matter?

Mr. Beatty.—There is no doubt some degree of selectivity with dalapon among the various grasses, but I question whether there is enough to take out one or more grasses from several others. Dalapon seems to enter through roots and the foliage so that unpredictable rainfall and growth factors would alter selectivity. We are not using dalapon as a selective herbicide in the U.S.A.

Mr. T. R. L. Waring (Plant Protection Ltd.).—To what extent are aircraft used in applying these herbicides, and is the major proportion applied by fixed wing or helicopter?

Mr. Beatty.—We are using aircraft extensively in our wheat area, and also in most of our brush work in the Northwest, Texas and throughout the South in our forest release programme. The airplane is used considerably in Canada for 2,4-D in wheat. Most of the aircraft application is fixed by wing stearman. The helicopter is being used more and more in the forest programme and I believe we will see an increase in aircraft spraying for herbicides in the U.S. The helicopter is much more expensive than the stearman, but it is being used in our hilly areas.

Mr. J. R. Macdonald (St. Chad's Nurseries).—What are the controls by either central or local governments in the U.S.A. for the regulations concerning the use of aeroplanes for spraying.

Mr. Beatty.—The regulations are of course complicated, but essentially no dusts or volatile esters may be employed. Spraying may only be done during certain climatic conditions. Also in certain cotton and grape growing areas, one may not use 2,4-D from the air. The invert emulsions referred to in the paper, it is hoped, will give much greater safety from spray.

Mr. J. L. Pattinson (Pattullo Higgs & Co. Ltd.).—How is the mass of detailed information about chemicals disseminated to the farmer who uses them in the U.S.A.?

Professor L. G. Holm (University of Wisconsin).—I should like to give you an example of the dissemination of weed control information and recommendations to the farmer, in my country. The vegetable research information from our own programme, together with that of my colleagues in America and other countries, is considered carefully by an extension specialist and myself. Together we write the recommendations for weed control for our farmers, and these are widely distributed.

The extension specialist then carries the information directly to our county advisers and to the farmers. He meets many farmers in large and small groups during the winter and summer and spring months but, perhaps more important, the county adviser becomes quite familiar with the recommendations in vegetables, fruit or nursery work, and through his own meetings and by personal contact he is able to disseminate the information and advice.

We have a long way to go in the education of our farmers, of course, but I feel that our difficulty in America is not so much the selection of the proper chemical as the education of the grower in the proper *use* of the chemical in his particular system of farm management. I am afraid many proper chemicals are wasted because of improper use.

Mr. J. L. Pattinson.—What chemical grass growth inhibitors are used in the United States? This information could be of value to the fruit grower and certainly to the household lawn owner.

Mr. Beatty.—The only chemical used on grass in the United States is maleic hydrazide. I would say this chemical is still in the development stage. It is used in a limited way on roadside spraying, however: maleic hydrazide differs in its ability to inhibit the different grasses, and if one has a mixed grass population, results are not satisfactory.