Bibliography of Herbicides in Forest Ecosystems

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BIBLIOGRAPHY OF HERBICIDES IN FOREST ECOSYSTEMS*

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This bibliography was prepared by Dr. Kimmins and Mrs. Fraker, Assistant Professor and Research Assistant respectively, of the Faculty of Forestry, University of British Columbia, Vancouver, B.C., under contract to the Pacific Forest Research Centre, Canadian Forestry Service, Environment Canada. The work is a part of the Centre's environmental research program. Comments of readers are welcomed and should be directed to:

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INTRODUCTION

Herbicides have become well established as one of the tools of forest land managers. They have been used for a variety of purposes, including brush control, stand improvement, chemical thinning, nursery weed control, wildlife habitat manipulation, control of phreatic vegetation in watershed management, and bark beetle control. Although accepted as useful agents by foresters certain sectors of the public have clamored against their continued use.

The source of the public anxiety can be readily traced to the recent extensive and repeated use of herbicides by the US military in Vietnam. Repeated blanket spraying of herbicides over extensive areas of tropical forest, coupled with the discovery of a highly toxic impurity in one of the herbicides being used (2,4,5-T), has alarmed both knowledgeable scientists and the lay public. Their concern reflects the general environmental awareness which had its genesis in Rachael Carson's Silent Spring. The appalling history of indiscriminate blanket applications of chlorinated hydrocarbons in the US in the 1950 to mid-1960 period left a large sector of the public with a deep seated apprehension of the use of insecticides. This concern has broadened to the use of herbicides, aided by the writings of a few individuals (e.g. Egler) who are as concerned about herbicides as Rachael Carson was over insecticides.

In spite of the legitimate public concern over the use of herbicides, the day for uniform condemnation of such management chemicals is past, just as blanket application of herbicides over large areas is justifiably considered an anachronism from pre-Silent Spring days. With the continued alarming increase in world populations, and with the high material standard of living in the developed countries, the demand for both renewable and non-renewable resources grows apace. This requires that we husband our renewable resources with greater care and attention than in the past. In particular, the degree to which we can accept the occupancy of highly productive land by undesirable vegetation is steadily being reduced, and the forest manager is being pressed to get all productive areas back into production without delay. Mechanical solutions to weed and brush competition have several attendant problems, such as their expense and their frequent failure to solve the problem. Herbicides, while not being a panacea by any stretch of the imagination, do appear to have considerable advantages over mechanical methods.

Forest land managers are confronted with a variety of problems of vegetation manipulation for which the best answer frequently appears to be herbicides, and yet the environmentally conscious public is exercising considerable indirect restraint on the use of herbicides. What is required to solve this dilemma as to whether or not we should use herbicides or in what manner they should be used is an evaluation of the ecological changes wrought by herbicide applications. The purpose of this bibliography is to provide either prospective herbicide users, herbicide banners, or herbicide researchers with an overview of the type of data available on which to make judgements about the use of herbicides in specific forest situations.

The bibliography is arranged by broad subject headings to facilitate entry into the literature. The references included are not restricted to forestry. While the bibliography is ostensibly concerned with forest ecosystems, the amount of information available for many aspects of herbicide use in forests is very inadequate and, therefore, all relevant literature encountered is included. In particular, very few studies of the ecological effects of herbicide have been conducted in British Columbia. Therefore, a wide range of literature covering agriculture, forestry, wildlife management, watershed management, and other aspects of herbicide use, in a wide range of ecological situations has been included, and it is hoped that a person concerned with herbicide use in a specific part of B.C. will find some information pertaining to the particular set of ecological conditions of concern. Since many articles pertain to more than one of the subject headings, they are listed under the subject reflecting the main thrust of the paper and cross referenced to secondary topics. Papers are listed within a subject group by date, and alphabetically by author within a single date. At the beginning of each subject group, a number of the citations are annotated to provide the user with a feeling for the type of data available. The annotations are intended as an adjunct to, rather than a substitute for, reference to the original papers; it was neither possible nor desirable to provide precis of sufficient detail to replace the original article. Finally, there is an author index for all papers cited.

In preparing this bibliography it became apparent that much of the available information on the use of herbicides refers to a level of biological organization substantially below that of the ecosystem. Topics such as the physiological effects of herbicides, persistence, fate in soils, decomposition and detoxification, toxicity data, empirical data on methods and problems of application, and the use of herbicides in forestry are well researched. There are numerous qualitative discussions of some very general ecological ramifications of herbicide use and this topic has been reviewed on a number of occasions. But there remains a number of very intractable questions with respect to such topics as the sub-lethal effects of herbicides on living organisms, the effects of different herbicides on the biogeochemistry of different types of forest ecosystems, on plant reproduction, on stability and diversity in an ecosystem, on interspecific competition, on ecological energetics, on succession, on the evolution of non-susceptible forms, and, until recently, on mutagenetic effects. The amount of information available on most of these topics is very limited. Most studies have been concerned with single applications and repeated use of herbicides over a long period of time has been virtually ignored. In short, there has been a tendency to focus on the effects of components of the ecosystem on herbicides, rather than the effects of herbicides on components of the ecosystem. In order to fully understand the ecological role of herbicides in ecosystems, we must have a good appreciation of both aspects.

I. HERBICIDES: THEIR USES, THEIR CHEMISTRY, METHODS, AND PERTINENT LEGISLATION

A. Uses in forestry

1. Anon. 1961. Herbicides and their use in forestry. Proc. Symp. Oregon State Univer., Corvallis, 127 pp.

   A symposium of 16 papers on the use of herbicides in forestry. The subject matter covered includes the development, formulation and application of herbicides, a description of various types of herbicides, and discussion of the use of herbicides in brush control.

2. Holt, H.A., and M. Newton. 1967. Preharvest killing of commercial timber. In: Herbicides and Vegetation Management Symp., Oregon State Univ., pp. 167-185.

   Describes experiments in Oregon using cacodylic acid to kill trees preharvest in order to reduce tree weight. Details are given of moisture reduction, loss of bark and foliage, insect attack, backflash to surrounding trees, degree of kill, disease and rot incidence, and fire hazard. 10 refs.

3. Bachelard, E.P. 1968. Herbicides - an ecological tool in forest management. Proc. Ecol. Soc. Australia 3: 77-82.

   A review of the use of herbicides in Australian forests, including a discussion of the efficacy of different herbicides and damaging effects on crop trees, and some comments on the physiological action of herbicides (concluding that little is known about this). 9 refs.

4. Barrons, K.C. 1969. Some ecological benefits of woody plant control with herbicides. Science 165: 465-468.

   The beneficial uses of herbicides for converting shrublands to grasslands are reviewed, as are the hydrological benefits of making this conversion. The many uses of herbicides in forestry, and in such programmes as tse-tse fly control are mentioned in support of the continued use of these chemicals. It is pointed out that many herbicides are selective, are biodegradable, and have low toxicity to many animals. The author asks that the responsible use of herbicides for land management not be condemned on the basis of current herbicide defoliation programmes in the Vietnam war. 19 refs.

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Cross references: 32, 33, 39, 412, 700, 880, 914, 945, 946, 1175, 1254, 1260, 1368

C. Use of herbicides for brush control and site preparation

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Late spring and early summer application of a variety of herbicide formulations were conducted to assess their efficiency at controlling growth of salmonberry and their effect on seedlings of sitka spruce and western hemlock. In all, 36 formulations, concentrations or combinations of herbicides were tried. PGBE esters of silvex and 2,4,5-T gave the best results. No refs.

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Brush removal for conversion to either grassland or forest has been achieved by bulldozer or broadcast burning of crushed brush. In both cases, herbicides may be necessary to prevent rapid regrowth; they may also be used in conjunction with the burning. Herbicides may also be needed after wildfire destruction of brushfields. Experiments with the use of various herbicides for control of brush are described, including the effect of data of spraying, damage to pine seedlings, and the degree of reduction of competition. No refs.

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Cross references: 18, 25, 33, 155, 1359, 1362, 1365

F. Use on rangeland

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Areas of eastern Idaho sprayed with 2,4-D within the previous three years were compared with adjacent unsprayed areas to assess the degree of range improvement. Of the 38 species of forbs encountered 15 were unharmed, 10 lightly damaged, and 13 moderately to heavily damaged. Mortality of trees and shrubs was lower, 12 of the 15 species being unharmed or only lightly damaged. The variability in response of both desirable and undesirable species indicates a need for careful consideration of vegetal composition when planning sagebrush control with 2,4-D. The possibility of a net deleterious effect on the range should be considered. 5 refs.

282. Brown, E.R. 1967. Impact of range improvement practices on wildlife habitat. In: Herbicides and Vegetation Management Symp., Oregon State Univ., pp. 243-247.

Herbicides are believed to have little direct effect on wildlife, a point recognized by most biologists but not accepted by the public. However, there is a considerable indirect effect through habitat changes. Some effects of control of brush on wildlife are reviewed, with particular emphasis on control of sage and litterbrush on important wildlife winter range. 15 refs.

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Describes experiments on 2,4-D control of rabbitbrush designed to test time of spraying and persistence of effect. It was found that when both soil and rabbitbrush were dry, there was a net increase in rabbitbrush after spraying: the 2,4-D reduced competition from forbs which were damaged under these conditions. Only when the soil was moist and the rabbitbrush was in the full-leaf stage was control obtained. After eight years, the improvement in grass production resulting from successful sprays was still 352 lbs/acre. 12 refs.

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This paper reports the responses of grassland vegetation on Grand Mesa, Colorado, to exclusion of livestock, reduction in livestock grazing, control of pocket gophers, and herbicide applications. In 1941 plots were fenced to exclude or control livestock. Gophers were trapped between 1941 and 1949, and 2,4-D was applied to certain areas between 1955 and 1958. Vegetation records were kept from 1941-1960 on all areas. The range improved slowly over the 19 years as the result of cattle exclusion, but there was almost as much improvement under light grazing. Nine years of partial gopher control resulted in a change in plant composition with an increase in the pernnial forbs eaten by the gophers while others decreased. Grasses and shrubs were little affected, but the effects of gopher control were modified by cattle grazing. In contrast, grass production increased greatly within a short time of herbicide applications which reduced competition from forbs and shrubs. It is recommended that the nature of the existing plant cover and other site characteristics should be considered when predicting the response of mountain grassland to specific management practices. 9 refs.

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Cross references: 4, 17, 184, 209, 363, 392, 444, 462, 470, 488, 491, 492, 597, 609, 616, 642, 736, 781, 952, 1061, 1215, 1384.

G. Use in wildlife habitat manipulation

352. Krefting, L.W., H.L. Hansen, and M.H. Stenlund. 1956. Stimulating regrowth of mountain maple for deer browse by herbicides, cutting, and fire. J. Wildlife Management. 20:434-441.

The efficiency of herbicides (2,4,5-T and 2,4-D), fire (propane torch or flame thrower), diesel oil, or cutting with an axe in stimulating regrowth of mountain maple was examined in Minnesota. This species is a staple and preferred browse species for deer in this area. 2,4-D was more effective than 2,4,5-T; breast-height applications were more effective than basal applications. Fire did not stimulate regrowth appreciably and was much less effective than the herbicides. The greatest regrowth was obtained by cutting with an axe, but this is slower than the herbicide method. However, because of the materials and equipment costs involved in the latter, the overall cost of the two methods was similar. 4 refs.

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Tests were conducted on the suitability of dalapon, amitrol, simazine, or combinations thereof for control of sod-forming grasses in the preparation of wildlife food patches (planted with corn) without any tillage. Satisfactory yields of corn were obtained using simazine or simazine plus dalapon. The paper includes details on costs, fertilizer needs, and timing of herbicide application. 6 refs.

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A short review of the uses to which herbicides may be put by the wildlife and fisheries manager for the purposes of habitat management. 7 refs.

355. Gysel, L.W. 1962. Vegetation changes and animal use of a power line right-of-way after the application of an herbicide. Down to Earth 18(1):7-9.

The effects of an Esteron 245 herbicide spray on the vegetation and use of a power right-of-way in Michigan by wildlife was studied between 1957 and 1961. Vegetation was mapped before and after the spray, and wildlife was observed for three years post-spray. The right-of-way was considered to be good habitat before spraying. During the first post-spray year there was a reduction in live plant cover, but by the second growing season there was a net increase in species diversity and number of stems over the pre-spray condition. This increase persisted through the fifth post-spray year, when the regrowth was sufficient to warrant an additional spray. No adverse effect of the herbicide on any animal species or on the habitat was observed. It was felt that there was a net improvement in habitat associated with the increased diversity. 2 refs.

356. Krefting, L.W., and H.L. Hansen. 1963. Use of phytocides to improve deer habitat in Minnesota. Southern Weed Conf., Proc. 16:209-216.

This is a brief review of the authors' research experience in the field of herbicide manipulation of deer habitat in the mid-west. The data are largely reported elsewhere. It is noted that judicious use of 2,4-D and 2,4,5-T can increase the proportion of preferred browse species and that deer show no aversion to eating herbicide-induced regrowth and may actually prefer it. There is evidence that deer prefer herbicide-treated areas for winter feeding, for summer browsing and bedding. 8 refs.

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Concern has been expressed over herbicide control of sagebrush because of the importance of this species to several species of wildlife. This paper reports a study of the effects of 2,4-D sagebrush control on the use of the treated areas by elk near Jackson, Wyoming. In particular, the project examined the change in spring distribution of elk by means of pellet counts and direct observation of the animals. Clipping experiments were conducted to determine the response of the vegetation to the treatment. On the more productive of the two plots treated there was a 79% decrease in sagebrush, a 253% increase in grass, no change in the forbs, and a total gain in forage of 17% (292 lbs.). However, nearly all of the remaining forage was desirable and usable. The percentage changes on the less productive area were similar. There was a 40% increase in elk use the first spring following treatment, and this increased by 55% the second spring on the richer site and by 90% in the less productive area. 10 refs.

358. Quimby, D.C. 1966. A review of literature relating to the effects and possible effects of sagebrush control on certain game species in Montana. Assoc. of State Game and Fish Commissioners, 46th Annual Convention (Butte, Montana).

A review of the literature in which the detrimental effects of herbicidal-control of sagebrush for wildlife is extensively documented. In addition to loss of browse for sagebrush-dependent pronghorn antelope and sage grouse, many forbs are heavily hit by 2,4-D sprays applied against sage brush. The food habits of pronghorn antelope, sage grouse, mule deer, elk, whitetail deer, moose, and bighorn sheep are documented from the literature, and it is pointed out that forbs constitute a very important dietary component. It is concluded that indiscriminate removal of sagebrush by herbicide sprays will have serious consequences for many wildlife. 16 refs.

359. Lawrence, W.H. 1967. Effects of vegetation management on wildlife. In: Herbicides and Vegetation Management symp., Oregon State Univ., pp. 88-93.

Wildlife is inseparably related to the plant species which provide its food and shelter, which can be beneficially or adversely affected by herbicides. Much of the use of herbicides is to convert vegetation from a form suitable for wildlife to a form which is commercially more attractive but less optimum for wildlife. These changes occur naturally through succession, herbicides merely being used to accelerate the process. There are three major categories of herbicide/wildlife relationships. Herbicides can be used in habitat maintenance, involving the stopping or retrogression of successional development. Conversely, herbicides can be used in habitat conversion, speeding successional development to a more productive (for timber) stage. Finally, herbicides can be used as an agent of wildlife population manipulation. Judicious use of herbicides can manipulate populations of both desirable and undesirable wildlife through selective control of food species or seral stages. 18 refs.

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The effectiveness of aerial applications of 2,4-D in improving deer habitat was examined over an eight-year period in Minnesota. The proportion and total abundance of the favoured browse species was increased by spraying, with the response varying by species and cover type. Grasses and sedges showed great increases while other herbs showed varied responses. No species was eliminated and it is suggested that the herbaceous vegetation changes resulted more from the change in light conditions than from the direct effects of the herbicides. Deer use, as measured by pellet counts, browse studies and bedding counts, increased on the sprayed plots. It is concluded that careful use of 2,4-D is an inexpensive and convenient method of improving browse production. 10 refs.

361. Bramble, W.C., and W.R. Byrnes. 1972. A long-term ecological study of game food and cover on a sprayed utility right-of-way. Purdue University, Agricultural Expt. Sta. Research Bull. No. 885. 20 pp.

Results are presented of a 19-year study of the effects of five different herbicide treatments on woody brush control and changes in the plant community on a power line right-of-way in an upland oak forest. Deer use of the differently treated areas was assessed by pellet-count techniques. No significant difference between deer use on the five treatments was apparent in 1970, 13 years after the initial herbicide treatment and four years after a second treatment. There was a considerable increase in deer use of the area as compared with pre-felling usage. Use by other wildlife also increased. The plant species forming a fairly stable 'low-community' on the treated areas were found to be more nutritious than the woody species invading unsprayed areas. 11 refs.

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Cross references: 37, 189, 282, 386, 746, 747, 748, 777, 1402.

H. Use on rights-of-way, industrial lands, and in aquatic systems.

382. Tweddle, B.A. 1971. Evaluation of spraying versus grooming and mowing in transmission line right-of-way brush control. British Columbia Hydro and Power Authority, 17 pp.

A review of the advantages and disadvantages of chemical (herbicides) versus mechanical (groomimg and mowing) methods of right of way maintenance in the interior of British Columbia. There is an economic evaluation of the two alternatives and it is concluded that from both economic and social standpoints the mechanical method is superior on many sites. No refs.

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389. Egler, F.E., and W.A. Niering. 1956. The Right of way Vegetation Committee of the Connecticut Botanical Soceity. Paper No. 3, 2 pp.

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M. Synergistic and antagonistic effects between herbicides and other chemical compounds

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N. The chemistry of herbicides

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While the fate and behavior of many herbicides is known, much less is known concerning mixtures of herbicides. In this study it was found that microbial degradation of dalapon was inhibited in the presence of amitrole. Phytotoxic residues persisted longer when these herbicides were applied together than alone. Dalapon did not affect the behavior of amitrole in muck soil, but affected its availability in a silty-clay loam. Although amitrole disappeared rapidly, its inhibitory effect on dalapon decomposition persisted. The effect is thought to be on the proliferation of dalapon-degrading organisms rather than on adaptation of the organisms to dalapon. 14 refs.

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The herbicidal activity of potassium azide and calcium cyanamid was evaluated singly and in combination. The combinations were synergistic in both field and greenhouse experiments. Laboratory experiments showed that the azide had no effect on the rate of disappearance of the cyanamid from soils, while the presence of cyanamid delayed the disappearance of azide. 11 refs.

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Effective and safe use of herbicides depends upon a knowledge of their chemistry and properties. Herbicides commonly used in forests, range and non-croplands are classified into inorganic, metallo-organic and organic families, and a brief description is given of the chemistry, solubility, application rates, mode of action, non-target toxicity, and type of use of the following: inorganic arsenicals, ammonium sulphamate, borates, sodium chlorate, organic arsenicals, petroleum oils, aryloxy alkanoic acids, benzoic acids, picloram-picoline acid derivatives, triazine herbicides, substituted uracils, substituted ureas, and amitrole. The article then discusses the importance of adsorption and translocation in controlling herbicide effectiveness, noting that an oil base aids foliar uptake while root and stem uptake is primarily from aqueous solutions. Absorption and translocation are very sensitive to molecular structure, hence the variation in the behavior of different formulations of the same or very similar substances. Environmental contamination problems are closely related to the herbicide's propensity to become absorbed onto surfaces. This can determine rates of leaching and soil migration, rate of biological decomposition, and uptake by target plants. A summary of the chemical formulation and properties of 52 herbicides is appended. 5 refs.

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A review of the role of surfactants in determining the phytotoxicity of herbicides. The main function attributed to surfactants has often been that of improving, wetting, spreading, solubilizing or altering other surface modifying properties of herbicides. However, more subtle and more specific herbicide-surfactant-plant surface interactions must be involved in cases of enhancement beyond that attributable to improved wetting. Both polar and apolar absorption pathways exist through the cuticle and surfactants may alter the availability of these pathways to an herbicide. There is no evidence at present to support theories of surfactant-facilitated herbicide translocation. 66 refs.

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This review examines the mode of action of amitrole which is of particular interest since it is one of the few herbicides which act equally on plants and microorganisms. Its effect on histidine metabolism, purine metabolism, and riboflavin metabolism are reviewed. Knowledge of the action of amitrole has been greatly furthered by studying its effect on microorganisms. Qualitative principles established in this manner have been extended to more complex organisms. 76 refs.

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O. Methods used in studying herbicides

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This study examined the use of a bioassay method based upon 72 hour root growth of seedlings in a culture of silica sand and herbicide solution. Lithium salt of 2,4-D, ammonium salt of amiben, CIPC, and trifluralin were used, the latter two as emulsifiable concentrates, in conjunction with a fine sand, a silt loam, and a muck soil. Herbicides were applied in aqueous solution to soil columns varying in length from 2-6"; the soil columns were leached with the equivalent of 2" of precipitation. Leachates and adsorption rates were measured by the root assay using sorghum and cucumber. The assay method was very sensitive to 2,4-D, CIPC, and trifluralin, all three producing similar levels of root inhibition. The technique was much less sensitive to amiben. 2,4-D and amiben showed high leaching mobility in the sand decreasing through the loam to a greatly reduced mobility in the muck soil. The other two herbicides exhibited much lower mobility but their behavior in the three soils showed the same pattern as 2,4-D and amiben. Adsorption of the herbicides by soil were predictably the inverse of rate of leaching, fine sands retaining little (20-50%) as compared with silt loam (40-90%) and muck soil (88-98%). 2,4-D and amiben showed far less retention in the fine sand and silt loam than did CIPC and trifluralin. It is concluded that this bioassay technique is faster and more sensitive than others for those herbicides affecting root growth. 13 refs.

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Growth aberrations in cucumber and Robinia seedlings used to bioassay low levels of herbicides in soils are described. Fine persistent, broad-spectrum herbicide compounds were investigated: fluometryne, prometryne, picloram, pyriclor and N-serve. The characteristic effects of each are described. 5 refs.

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An approach to evaluating the use of herbicides is suggested. This involves a consideration of the herbicide and the recipient environment prior to application, and a post-application assessment. As an illustration, the use of fenuron for the release of larch from a hardwood overstorey is evaluated according to the proposed procedure. The procedure is intended to help pesticide users to achieve more satisfactory and rational use of pesticides. No refs.

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P. Legislation pertaining to herbicides; organizations studying herbicides

712. Council of Forest Industries of British Columbia. 1972. Forest pesticide handbook of British Columbia. Vancouver, B.C., 101 pp.

This periodically updated manual reviews pesticide legislation in B.C., outlines requirements for submitting pesticide applications. Ranges of pesticides, and safety factors are reviewed, and a description of individual insecticides and herbicides are given. There is a listing of all commonly used pesticides including a lot of technical data.

713. Frans, R.E., D.E. Davis, and J.B. Weber. 1972. Behavior of specific herbicides in plants and soils. Southern Cooperative Series Bull. No. 167, Arkansas Exp. Sta., Univ. of Arkansas, Fayetteville, Ark., 26 pp.

The historical development and accomplishments of the S-18 Technical Committee are given as well as a listing of herbicides studied and university graduate theses produced on the project. There is a summary of recent findings on the effects of climate and edaphic factors on movement, persistence, and toxicity of herbicides in the soil; on absorption, translocation, accumulation, and degradation of herbicides in plants; on the effects of herbicides on anatomical and morphological responses, seed germination and growth, and selected metabolic systems. The paper refers specifically to agricultural weeds in the southern United States and there is a list of 116 references concerning the control of weeds in this region; many of these are basic studies of herbicides. While much of the information is specific to agricultural problems, there are some points of interest to herbicide applications in general. 116 refs.

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728. Mann, J. 1970. Weed control research by the biological section, Department of Lands, at the Alan Fletcher Research Station. PANS 16(2):389-392.

729. Ontario Department of Health. 1970. Revised registration status of 2,4,5-T in Canada. News and Views, Bulletin of the Pesticides Control Service 5(2):1-10.

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R. Herbicides and fire

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S. Philosophy of herbicide use

744. Egler, F.E. 1958. Science, industry, and the abuse of rights of way. Science 127:573-580.

A discussion of approaches to "brush" control on rights-of-way in the U.S. in the 1950's. The folly of vegetation elimination vs. vegetation manipulation is pointed out and an appeal is made for an ecological approach to the management of right-of-way vegetation. It is pointed out that in the context of the paper the need is not for more research, but for the communication, utilization and application of existing knowledge. 1 ref.

745. Lichy, C.T. 1967. Discovery and development of new herbicides. In: Herbicides and Vegetation Management Symp., Oregon State Univ., pp. 72-82.

There is a review of the four stages involved in the discovery and development of new herbicides by Dow Chemical Co. Stage 1, exploratory research, involves laboratory screening for toxicity and usability. Stage 2 involves determining the potential values and limitations of candidate substances, including preliminary tests of toxicity to non-target organisms. Stage 3 examines production potentialities, effects on non-target organisms, residue problems and metabolic alteration. Stage 4, reached after 3 to 5 years, involves field testing under a variety of conditions to validate experimental data obtained in Stage 3. A detailed flow chart is presented showing the stages of this development.

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756. Freed, V.H. 1965. Chemicals and the control of plants. In: Research in pesticides. C.O. Chichester, ed., Acad. Press. pp. 159-171.

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758. Legrand, H.E. 1966. Movement of pesticides in the soil. In: Pesticides and their effects on soils and water. Soil Sci. Soc. Amer. ASA Special Publ. 8:71-77.

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767. Weber, J.B., and T.J. Monaco. 1972. Philosophy and ingredients of an advanced weed science course. Proc. Southern Weed Sci. Soc. 25:480-485.

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II. ECOLOGICAL EFFECTS OF HERBICIDES

A. Effects on biogeochemistry

768. McCalla, T.M., T.J. Army, and A.F. Wiese. 1962. Comparison of the effects of chemical and sweep tillage methods of summer fallow on some properties of Pullman silty clay loam. Agron. J. 54:404-407.

The study investigated the effects of sweep tillage and herbicides (dalapon, amitrole, 2,4-D and PBA) on pH, soil organic matter, fungi, bacteria, nematodes, nitrate content, aggregate stability, and bulk density in the field (silty clay loam) and on nitrification rate, and oxygen uptake in the laboratory. Herbicides reduced nitrification in the surface inch of soil during the summer suggesting that there may have been temporary interference with microbes associated with the nitrogen cycle. Herbicides did not change soil fungi, but there was a significant reduction in the numbers of nematodes. Bulk density and soil aggregation were essentially similar for both types of tillage. Only at very high rates of application did herbicides depress oxygen uptake in incubator studies. The effects on nitrification in the incubator studies were variable. At some application rates there was a stimulation, at others a depression in the production of nitrate. At field application rates there was an initial depression followed by a moderate stimulation in nitrification. It is concluded that organic herbicides can be used at normal rates of application without detrimental effects on soil microflora or physical and chemical soil properties, although it may aggravate nitrogen deficiencies under some conditions. 22 refs.

769. Likens, G.E., F.H. Bormann, N.M. Johnson, D.W. Fisher, and R.S. Pierce. 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecol. Mono. 40:23-47.

This is a summary of four years of team research at the Hubbard Brook watershed installation, some of which is reported in earlier papers. The study involved monitoring inputs and outputs of chemicals in the form of precipitation and streamwater, respectively. This was conducted for a period of about six months before all vegetation on one of the watersheds was cut and left lying in place with minimum site disturbance. Herbicide (bromacil) was applied in the following June, six months after cutting, and a further application (of 2,4,5-T ester) was made the following summer to scattered regrowth of stump sprouts. Very large increases in the concentrations of major ions in streamwater resulted (417% for Ca^{++}, 408% for Mg^{++}, 1558% for

for K^+, and 177% for Na^+ during the two years following herbicide treatment) and nitrate ions far exceeded U.S. Federal pollution levels. The large ionic losses were attributed to a disruption of the nitrogen cycle by the cutting plus herbicide treatment. A considerable amount of other data is presented. 54 refs.

770. Martin, J.P. 1972. Side effects of organic chemicals on soil properties and plant growth. In: Organic chemicals in the soil environment. Goring, C.A.I., and J.W. Hamaker, eds., Marcel Dekker Inc., pp. 733-792.

While most organic chemicals used appropriately do not have a major impact on soils, some may have a profound effect on soil properties which may be harmful or beneficial to plant growth. Continued use of organic chemicals may require a better understanding of such impacts. This review splits the topics into five groups: soil biological properties, including the ecological effects of herbicides thereon and their significance; soil chemical properties; soil physical properties; increased growth response; decreased growth response. It is concluded that most organic chemicals are used as a carbon and energy source by soil organisms and so are decomposed. Some, such as DDT are highly resistant: others highly degradable. The results of this utilization may be an alteration in the composition and abundance of the soil microbial population. However, most herbicides and insecticides at normal dosage rates have little effect on soil microorganism. Soil fumigants, fungicides and certain insecticides have a much greater effect. Many materials result in an increase in soluble nutrients derived from the decomposition of organisms killed by the chemical. Sometimes there is a reduction in availability of nutrients. The overall conclusion is that the proper use of organic chemicals in the soil environment will not render soils sterile or permanently infertile. 377 refs.

771. Cope, O.B. 1964. Agricultural chemicals and fresh water ecological systems. In: Research in pesticides. (O. Chichester (ed.), Academic Press, Inc., New York, pp. 115.

772. Ball, R.C., and F.H. Hooper. 1966. Use of ^{74}As-tagged sodium arsenite in a study of effects of a herbicide on pond ecology. Symp. Isotopes in Weed Research, International Atomic Energy Agency, pp. 149-163.

773. Cope, O.B. 1966. Contamination of the fresh water ecosystem by pesticides. Pesticides in the environment and their effects on wildlife. J. Appl. Ecol. 3(Suppl.):33-44.

774. Montgomery, M.L., and L.A. Norris. 1970. A preliminary evaluation of the hazards of 2,4,5-T in the forest environment. U.S.D.A. Forest Service, Pacific Northwest Forest and Range Expt. Sta. Research Note. PNW-116. 11 pp.

775. Grossbard, E. 1971. The effect of repeated field applications of your herbicides on the evolution of carbon dioxide and mineralization of nitrogen in soil. Weed Res. 11:263-275.

B. Effects on plant communities, including ecological succession

776. Keith, J.O., R.M. Hansen and A.L. Ward. 1959. Effect of 2,4-D on abundance and foods of pocket gophers. J. Wildl. Mgmt. 23: 137-45.

Areas of range land on the Grand Mesa in Colorado were sprayed with 2,4-D to examine the effect of altering the vegetative cover on the abundance of pocket gophers. Production of perennial forbs declined from 396 lbs/acre to 67 lbs/acre, a reduction of 85%. Grass production increased 37%. The population of pocket gophers declined 87%, reflecting a high proportion of forbs in their diet, which was 82% forbs: 18% grass prior to spraying and 50% forbs: 50% grass after spraying. Feeding experiments indicated that the decline in gophers was not associated with direct toxic effects of 2,4-D, although caged gophers exhibited a preference for untreated food. 21 refs.

777. Schacht, A.J., and H.L. Hansen. 1963. Long-term vegetational changes following aerial application of 2,4-D and 2,4,5-T in Northern Minnesota. Univ. of Minnesota, School of Forestry.

A report of a vegetation survey, conducted in Minnesota, of forest areas which had been sprayed five or more years earlier. 100 mil-acre plots were examined in each sprayed area and an adjacent unsprayed area with comparable vegetation cover. Tree, brush, and ground cover was assessed. The objectives of the study were to assess vegetation changes resulting from the spray treatment and assess the significance of these for wildlife and forest regeneration. The general conclusion was that herbicide treatment was very effective in releasing sapling conifers but less so for conifer seedlings. Vegetation changes increased berry species, ground cover and low shrubs, all of which is beneficial for wildlife. 44 refs.

778. Newton, M. 1967. Response of vegetation communities to manipulation. In: Herbicides and Vegetation Management, M. Newton, ed., Oregon State Univ., pp. 83-87.

Herbicides are used to manipulate the composition of plant communities. In order to understand the ecological implications of such changes it is necessary to understand the normal changes which occur in unmanaged communities. The basic principles of ecological succession are reviewed and the influence of climate on succession in different types of ecosystem is discussed. No refs.

779. Tschirley, F.H. 1967. Research report - response of tropical and subtropical woody plants to chemical treatments. Agricultural Research Service, U.S. Dept. of Agriculture. ARPA Order No. 424, U.S. Dept. of Defense. 197 pp.

This report summarises the work of 12 researchers under contract to the U.S. Department of Defense. The overall project was to determine the best herbicide and application techniques for military use in Southeast Asia. The field work was conducted in Texas and Puerto Rico, and the results extrapolated to ecologically similar habitats of military concern in Southeast Asia. There are 12 chapters which: compare the ecology of the three areas; evaluate herbicides in laboratory, greenhouse, woody plant nursery, and field situations; examine behaviour and residues in soils; evaluate foliar applications of herbicides; examine defoliation of tropical and subtropical forests by herbicides and the accompanying effects on visibility; examine herbicide application techniques and penetration of spray through forest

780. Westhoff, V., and P. Zonderwijk. 1960. The effects of herbicides on the wild flora and vegetation in the Netherlands. In: Symp: The ecological effects of biological and chemical control of undesirable plants and animals, 8th Technical Meeting, I.U.C.N.: 69-78.

781. Douglas, G., C.J. Lewis, and H.C. McIllvenny. 1965. The effect of the bipyridyl herbicides on hill communities and their role in the improvement of hill grazing. J. Brit. Grassland Soc. 20:64-71.

Cross references: 181, 289, 299, 311, 351, 361, 365, 366, 367, 368, 369, 373, 376, 388, 393, 751, 823, 844.

C. Effects on community diversity and stability

782. Harper, J.L. 1957. Ecological aspects of weed control. Outlook on Agric. 1: 197-205.

An ecological evaluation of the status of agricultural weeds, which discusses the origin and nature of these plants in the U.K. The stability of weed populations and their interactions with biotic components of their environment are discussed. Weed floras of a region may undergo great changes over long periods, largely as the result of immigration of new species. However, weed populations are characterized by great stability which makes it unlikely that the use of herbicides will create major weed problems from previously minor, but herbicide-resistant species. The danger of herbicide-sensitive species becoming resistant is thought to be one of the major potential problems. 44 refs.

Cross references: 355, 369

D. Effects on food chains

783. Macek, K. J. 1969. Biological magnification of pesticide residues in food chains. In: The biological impact of pesticides in the environment. Environ. Health Ser. 1, Oregon State Univ., pp. 17-21.

Cross references: 782, 1071

E. Effects on genetics

784. Wuu, K.D. and W.F. Grant. 1966. Induced abnormal meiotic behavior in a barley plant (Hordeum vulgare L.) with the herbicide Lorox. ΦYTON 23(1):63-67.

Barley seeds were soaked for 24 hours in 500 ppm of Lorox (3-(3,4-dichlorophenyl)-1-methyoxy-1-methylurea), and pollen mother cells were examined subsequently in the resulting plants. Cytological observations were carried out from the first meiotic division through microspore formation. All cells showed abnormal meiotic behaviour including chromosome stickiness, chromosome clumping, "chromatin body" formation, cytoplasmic furrowing, unequal distribution of chromatin material into daughter cells, and asynchronous and multiple cell division. The action of Lorox is considered to be that of a radiomimetic compound. 8 refs.

785. Wuu, K.D. and W.F. Grant. 1967. Chromosomal aberrations induced by a plant growth retarding chemical (B-995) in barley (Hordeum vulgare). Bot. Bull. Academia Simica 8:191-198.

Barley seeds exposed to B-995 (a plant growth retardant) at 500-1500 ppm for 6-24 hours had chromosomal aberrations in the C_1 generation of 2.84-5.64%, This compared with 4.93-9.15% produced by 2000-5500R x-rays. Percentage of pollen mother cells in the C_1 and C_2 generations was very low; scarcely above the controls. The root tip aberrations were very low in the C_2 generation indicating very low transmission rate of chromosomal aberrations. 10 refs.

786. Wuu, K.D., and W.F. Grant. 1967. Chromosomal aberrations induced in somatic cells of Vicia faba by pesticides. The Nucleus 10:37-46.

Aqueous solutions of nine herbicides, three insecticides, two insect chemosterilants and one fungicide were prepared at several concentrations (10-600 ppm). 10-15 day old Vicia faba seedlings were placed with their roots in aerated solutions of the pesticides for 3-12 hours followed by 24 hours in tap water. Root tips were examined cytologically. All pesticides were highly effective at inducing chromosome aberrations in root cell tips at rates of 9.2-21.3%. Generally, the longer the exposure time, the greater the percentage aberration. The most common chromosome irregularities observed were fragments and anaphase bridges, but chromosome breakage in the satellite region of the SAT-chromosomes was also increased. 7 refs.

787. Davring, L. and M. Surner. 1971. Cytogenetic effects of 2,4,5-trichlorophenoxyacetic acid on oogenesis and early embryogenesis in Drosophila melanogaster. Hereditas 68:115-122.

It is reported that other studies have attributed chromosome aberrations and other disturbances of somatic cells of higher plants to the action of phenoxyacetic acids, but that genetic studies of the effects of herbicides on the fauna are still very rare. In this study, very small doses of 2,4,5-T were shown to affect early oogenesis and to cause chromosome disturbances which could lead to sterility, depending on the age of the female fly at the time of exposure. The 2,4,5-T used was a butoxyethylester with a guaranteed level of dioxin of less than 0.1 ppm. 17 refs.

788. Grant, W.F. 1971. The case for mutagenic testing of chemical pollutants. Can. Field Nat. 85:203-204.

The conflict of attitudes between professionals responsible for short-term effects of pesticides (e.g. classical toxicologists) and those concerned over the long-term effects (e.g. geneticists, cancer researchers) is illuminated. A plea is made for requiring the testing of the mutagenicity as well as the toxicity of propsective chemicals as a requirement for their registration.

789. Grant, W.F. 1972. Pesticides - subtle promoters of evolution. Symp. Biol. Hung. 12:43-50.

A review of the ways in which pesticides can affect the course of evolution in target and non-target organisms. Evolution occurs principally through mutation, genetic recombination, natural selection and isolation. Pesticides can operate on all of these mechanisms. The effects of herbicides on plant genetics is reviewed including topics such as pollen sterility, production of mutants, and reduction in seed production. 41 refs.

790. Tomkins, D.J. and W.F. Grant. 1972. Comparative cytological effects of the pesticides menazon, metrobromuran and tetrachloroiso phthaonitrile in Hordeum and Tradescantia. Can. J. Genet. Cytol. 14:245-256.

Dormant seeds of barley were soaked in aqueous solutions of three pesticides: an s-triazine insecticide (MEN), a substituted urea herbicide (PAT), an aromatic hydrocarbon fungicide (DAC), and a chemical alkalizing agent (EMS). Percentage germination, seeding height and frequency of chromosomal aberrations were examined subsequently. Somatic mutations in inflorescences of Tradescantia treated with solutions of these chemicals were also examined. The effects on the barley were compared with x-ray radiation of the seed. The herbicide reduced germination percentage, seedling height and miotic index in the barley. While the EMS and x-ray treatment produced cytogenetic effects, the only pesticide to produce an effect was the herbicide, which induced severe physiological effects. 27 refs.

791. Doxey, D., and A. Rhodes. 1949. The effect of the plant growth regulator 4-chloro-2-methylphenoxyacetic acid on mitosis in the onion (Allium cepa). Annuals of Botany (London), Series 2 13:105-111.

792. Croker, B.H. 1953. Effects of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid on mitosis in Allium cepa. Bot. 6az. 114: 274-283.

793. McGahen, J.W., and C.E. Hoffmann. 1963. Action of 5-bromo-3-sec-butyl-6-methyluracil as regards replacement of thymine in mouse DNA. Nature 199: 810-811.

794. McGahen, J.W., and C.E. Hoffman. 1966. Absence of mutagenic effects of 3- and 6- alkyl-5-bromouracil herbicides on a bacteriophage. Nature 209 (5029): 1241-1242.

795. Wuu, K.D., and W.F. Grant. 1966. Morphological and somatic chromosomal aberrations induced by pesticides in barley (Hordeum vulgare). Can. J. Genst Cytol. 8 (3): 481-501.

796. Wuu, K.D., and W.F. Grant. 1967. Chromosomal aberrations induced by pesticides in the meiotic cells of barley. Cytologia 32: 31-41.

797. Stroyev, V.S. 1968. Cytogenetic activity of herbicides. Simazine and maleic hydrazide. Genetika 4: 130-134.

798. Lofroth, G., C. Kim, and S. Hussain. 1969. Alkylating property of 2,2-dichlorovinyl di methyl phosphate: A disregarded hazard. Environmental Mutagen Society, Newletter 2: 21-26.

799. Grant, W.F. 1970. Pesticides and heredity. Macdonald Jour. 31: 211-214.

800. Grant, W.F. 1971. Book review of Chemical mutagenesis in mammals and man. The Canadian Field-Naturalist 85 (3): 268-269.

801. Admed, M., and W.F. Grant. 1972. Cytological effects of the pesticides phosdrin and bladex on Tradescantia and Vicia faba. Can. J. Genet. Cytol. 14: 157-165.

802. Grant, W.F. 1972. Book review of: Chemical mutagens: Environmental effects on biological systems and Chemical mutagens: Principles and methods for their detection. The Canadian Field-Naturalist 86 (1): 106-107.

Cross references: 622, 1608

F. General ecological effects

803. Hanson, W.R. 1952. Effects of some herbicides and insecticides on the biota of North Dakota marshes. J. Wildl. Mgmt. 16:299-308.

Field applications of 2,4-D amine in water, 2,4-D ester in oil, chlordane, toxaphene, and DDT were made to small shallow marshes. The two herbicides produced a rather similar heavy kill of dicotyledenous plants, although these were replaced shortly. Damage to monocotyledons was greater for the ester than the amine formulation. The only observed effects on animal life were a few insects thought to have been killed by the oil carrier. The results of the insecticide sprays are presented. 14 refs.

804. Gratkowski, H. 1967. Ecological considerations in brush control. pp. 124-140, In, Herbicides and Vegetation Management in Forests, Ranges, and Noncrop Lands. Proc. Symp. Oregon State Univ., Corvallis.

Success in the use of herbicides depends upon a knowledge of the ecology of competing vegetation. Various aspects of ecosystems which are basic to understanding the ecological role of herbicides are reviewed: biotic interactions, solar radiation, and competition for water and nutrients. The silvicultural implications of these are discussed as is the role of fire in the ecology of brush species. 27 refs.

805. House, W.B., L.H. Goodson, H.M. Godberry, K.W. Dockter. 1967. Assessment of ecological effects of extensive or repeated use of herbicides. Adv. Research Projects Agency ARPA order No. 1086 U.S. Dept. Defense. 369 p.

This is a comprehensive review of herbicide usage, the toxicological effect of herbicides, the persistance of herbicide and the broad ecological effects of herbicides.

806. Galston, A.W. 1968. Defoliants. In: Chemical and Biological Warefare, S. Rose (Ed.), G.G. Harrap & Co. Ltd., London, pp. 62-75.

A review of the military use of herbicides in Vietnam, including discussion of the effects of defoliation, the mechanism of action, and the effects on the S.E. Asian environment. There is a brief section on the response of the U.S. scientific community to the military use of herbicides in Vietnam.

807. Karnig, J.J. and B.B. Stout. 1969. Diameter growth of northern red oak following understorey control. Black Rock Forest Papers No. 30, 16p.

Diameter growth of northern red oak was studied in a 70 year old stand which had been either heavily thinned in 1956 with underbrush removed by 2,4,5-T sprays in 1959 and 1961, or heavily thinned in 1956 with no brush treatment. DBH's were measured in 1962, 1963 and 1964. The thinning resulted in an increased growth compared with the unthinned control, but the brush removed had only a modest overall effect on basal area increment. There was, however, a considerable increase in the growth of trees over 11 inches DBH while trees less than 11 inches DBH showed an apparent degression in growth. No explanation is given for this observation. 12 refs.

808. Orians, G.H., and E.W. Pfeiffer. 1970. Ecological effects of the war in Vietnam. Science 168: 544-554.

A review of the ecological impacts of herbicide defoliation in Vietnam, including a discussion of the effects on vegetation (mangrove and upland forests), animals and rubber plantations, Herbicide toxicity and the effects of accidental defoliation are discussed. It is concluded that the ecological consequences of the war, and in particular the herbicide defoliation, are severe. 21 refs.

809. Baffey, P.M. 1971. Herbicides in Vietnam: AAAS study finds widespread devastation. Science 171: 43-47.

This is a review of the findings of the AAAS Herbicide Assessment Commission which examined the military use of herbicides in Vietnam. The report concludes that one fifth to one half of South Vietnam's mangrove forests have been destroyed and that little new growth is occurring after several years. Perhaps half the trees in the mature hardwood forests near Saigon are dead and bamboo threatens to take over the area for decades to come. While no cause/effect relationship has been established between high rates of still-births and birth defects in heavily sprayed areas and the herbicide spraying operations, no satisfactory alternative explanation has yet been advanced. A number of other reports by scientists critical of the herbicide spray programme are discussed. No refs.

810. Norris, L.A. and D.G. Moore. 1971. The entry and fate of forest chemicals in streams. pp 138-159. In: Forest Land Uses and Stream Environment. Forest Extension, Oregon State University, Corvallis.

The behavior of pesticides and fertilizers in forest environments is reviewed including initial distribution, drift and volatolization losses, and movement to streams from the air, forest flow, soil, and vegetation. The fate of pesticides and fertilizers (nitrogen) in the aquatic environment is discussed. 82 refs.

811. Harper, J.L. 1956. The evolution of weeds in relation to resistance to herbicides. Proc. 3rd Brit. Weed Control. Conf., Blackpool, 1956: 179-188.

812. Rudd, R.L. 1958. The indirect effects of chemicals in nature. Papers given at 54th Ann. Convention Natl. Audubon Soc., New York, N.Y.:12-16.

813. Geier, P.W., and L.R. Clark. 1960. An ecological approach to pest control. In: Symp.: The ecological effects of biological and chemical control of undesirable plants and animals, 8th Technical Meeting. I.U.C.N.: 10-18.

814. Anon. 1965. Restoring the quality of our environment. Report of the Environmental Pollution Panel. U.S. President's Sci. Advisory Comm. 317 pp.

815. Rudd, R.L. 1966. Pesticides and the living landscape. The University of Wisconsin Press: Madison, 320 pp.

816. Gratkowski, H.J. 1969. Ecological considerations in brush control. Timber Management Training Session, Six Rivers National Forest, California. Unpublished paper. 14 pp.

817. Molski, B. 1969. Defoliation of forests in Vietnam. Sylwan. 113 (8): 21-38.

818. Tschirley, F.H. 1969. Defoliation in Vietnam: the ecological consequences of the defoliation program in Vietnam are assessed. Science 163 (3969): 779-786.

819. Galston, A.W. 1970. Letter to the editor. Science 167: 237.

820. Howard, B. 1970. The Forest Service and herbicides. USDA Forest Service, P.N.W. Forest and Range Expt. Sta. 39pp.

821. Newton, M., and L.A. Norris, 1970. Herbicide usage. Science 168 (3939): 1606-1607.

822. Whiteside, T. 1970. Defoliation. Ballantine / Friends of the Earth: New York. 168 pp.

823. Woodwell, G.M. 1970. Effects of pollution on the structure and physiology of ecosystems. Science, N.Y. 168 (3930): 429-433.

824. Norris, L.A. 1971. The Behavior of chemicals in the forest. In: Pesticides, Pest Control and Safety on Forest Range Lands. Oregon State University, School of Agriculture. pp. 90-106.

Cross references: 558, 744, 1025

G. Effects of herbicide vapors

825. Mullison, W.R., and R.W. Hummer. 1949. Some effects of the vapor of 2,4-dichlorophenoxyacetic acid derivatives on various field-crop and vegetable seeds. Bot. Gaz. 111: 77-85.

826. Baskin, A.D. , and E.A. Walker. 1953. The responses of tomato plants to vapors of 2,4-D and/or 2,4,5-T formulations at normal and higher temperatures. Weeds 2: 280-287.

827. Scotten, J.W. 1965. Atmospheric transport of pesticide aerosols. U.S. Dept. Health, Ed., and Welfare, Office of Pesticides, Washington D.C., 30 pp.

828. Anon. 1969. Woody weed control: low volatile esters of 2,4,5-T Rep. For. Res. For. Comm., Land. 1968/1969: 77-8.

H. Communication of herbicide information

829. Egler, F.E. 1964. Pesticides - in our ecosystem. Amer. Sci. 52:110-136.

830. Gardner, M.R. 1971. Pesticides and people. In: A role for pesticides. Unpublished paper. 8 pp.

Cross references: 752

III. EFFECTS OF HERBICIDES ON SOILS

A. Movement and persistence in soils

831. DeRose, H.R., and A.S. Newman. 1948. The comparision of the persistence of certain plant growth regulators when applied to soil. Soil Sci. Soc. America Proc. 12: 222-226.

There is a review of the early papers on the relative persistence of 2,4-D and 2,4,5-T and on the importance of soil organic matter, quantity of precipitation, soil pH, and microbial activity in affecting persistence. In a greenhouse study in an unidentified soil, no 2,4-D was identified by bioassay (soybeans) after 67 days irrespective of application rate, while 2,4,5-T was still detectable after 330 days at the heaviest rate of application (12.5 mgm/lb soil). In a field study, 2,4-D, 2,4,5-T and 2-Me-4-Cl were applied as dusts to unidentified agricultural soils at either 5 or 20 lbs/acre. A soybean bioassay detected only 2,4,5-T after 93 days; rate of application had little effect on persistence. Temperature affected the persistence of all three, with a doubling of the rate of disappearance between 10°C and 30°C. 2,4-D disappeared in 21-36 days at 30°C, while 2,4,5-T disappeared in 166-190 days at the same temperature. Rate of disappearance increased rapidly with increasing soil moisture. At field capacity and 25°C 2,4-D disappeared in one week. Sterilization of soils by autoclaving was found to radically increase herbicide persistence: there was no measurable loss in sterilized soils during the experiment while all activity disappeared in 3 to 6 weeks in the unsterilized soils. It is concluded that herbicides will persist in dry areas much longer than warm moist areas, and also under situations which do not favour microbial activity. 10 refs.

832. Ogle, R.E., and G.F. Warren. 1954. Fate and activity of herbicides in soils. Weeds 3 (5): 257-273.

The study was concerned with the effects of soil type, exchange capacity, temperature, and amount of rainfall on breakdown, leaching, and retention of the following herbicides in soil: 2,4-D, NPA, TCA, CMU, and CIPC. The literature quotes 2,4-D persistence data under field conditions as varying from less than 10 days to 14 weeks. This variation is attributed to variation in microbial activity under environmental control. The literature on this topic is reviewed as is the topic of soil migration rates for 2,4-D. The smaller volume of comparable literature on the other herbicides is similarly reviewed. Experiments were undertaken with all herbicides on 3 soils varying in organic matter from 1-82%, in exchange capacity (meg/100gm) from 3-127, and bulk density from 0.4-1.5. Activity of herbicides was assayed with crabgrass (Nigitoria sanguinalis). For all herbicides decomposition increased with temperature and with % soil organic matter, and the period required for total inactivation increased with rate of application. Rate of herbicide leaching in columns of soil were studied using constant volumes of water, as was the relative amount of rainfall required to produce a given soil migration. TCA was found to be the most mobile followed by 2,4-D and NPA. CMU moved even less, while CIPC was the most resistant to leaching. The second leaching experiment revealed considerable differences between the herbicides in their leaching behavior on the three soils; the role of organic matter in rates of leaching varies between different herbicides. The influence of exchange capacity and % organic matter on the movement of NPA was studied on 13 soils. Correlation coefficients of 0.88 and 0.74 were obtained for exchange capacity and organic matter, respectively: in both cases this was improved by excluding the much (highest organic matter) soils. The biological impact of herbicides will depend upon both rate of detoxification and rate of soil migration. Different herbicides vary greatly in these respects and so, therefore, do the environmental problems associated with their use. 27 refs.

833. Crafts, A.S., and H. Drever. 1960. Experiments with herbicides in soils. Weeds 8 (1): 12-18.

Bioassay employing kanota oats was used to examine the comparative initial toxicity and persistence on three loamy agricultural soils of IPC, CIPC, monuron, fenuron, dalapon, TCA, CMIPC, 2,3,6-TBA at 14 concentrations ranging from 0.1 ppm to 819 ppm over post-application periods of 1200 days. Monuron and fenuron were very persistent at all but the lower concentrations, with 2,3,6-TBA, CMIPC, CIPC, dalapon, TCA and IPC showing decreasing persistence in that order. Initial toxicities (to kanota oats) of seven of these are given in decreasing order as 2,3,6-TBA, CMIPC, TCA and dalapon, CIPC and fenuron, and monuron. It is pointed out that the persistence of some of these materials poses considerable environmental problems, particularly if the herbicides are susceptible to leaching to lower soil horizons where conditions promote their persistence. It is pointed out that bioassay data reflects the sensitivities of the bioassay species and may not hold true in other situations. 13 refs.

834. Freed, V.H., and W.R. Furtick. 1961. The persistence of amitrole in soil when used for chemical fallow. The Hormolog. 3(1): 2 pp.

Previous literature shows that amitrole (3-amino-1,2,4-triazole) is very susceptible to biological degradation even under suboptimal conditions. It is also very susceptible to absorption by soil constituents. This paper deals with the persistence of amitrole in various agricultural soils of the wheat growing region of Oregon. The herbicide was applied at one or two lbs/acre in the fall and the soils were sampled at 0 and 6 inch depths in late winter and the following spring. Samples were extracted with $CaCl_2$ + NH_4Cl in aqueous solution, the amitrole being measured colorimetrically after appropriate preparation of the extract. Detection limits using this method varied on different soils from 0.01-0.05 ppm. No detectable amitrole was found in any of the samples analysed. 4 refs.

835. Behrens, R. 1962. Soil residue from herbicides. Agric. Chem. 17 (34): 78-79.

Discusses briefly factors contributing to loss of herbicides from soil, including vaporization, adsorption, leaching and chemical, photo-chemical or biotic degradation.

836. Bailey, G.W., and J.L. White. 1964. Review of adsorption and desorption of organic pesticides by soil colloids, with implications concerning pesticide bioactivity. Agric. and Food Chemistry. 12: 324-332.

This review covers 161 references up to 1963, and is split into 10 major sections: (1) Nature of the colloid: there is an inverse relationship between soil organic matter and clay content, and herbicide bioactivity and leachability. Considering organic matter, total clay, cation exchange capacity and pH, all of which are correlated, organic matter is the best predictor of adsorption. Organic matter has the greatest adsorptive potential followed by montmorillonite and vermiculite. The degree of desorption possible varies greatly with different colloids. (2) Nature of adsorbate: herbicides vary in adsorptive behavior. Within one chemical family this relates to solutility. In different families, chemical reactivity and the basicity or acidity in aqueous solution become complicating factors. (3) Soil reaction: optimum conditions for adsorption at different pH's for different herbicides. This is thought to operate through control of the degree of molecular dissociation, the total charge on the inorganic soil colloids, and effects on solubility. (4) Effect of the saturating cation: the degree of adsorption is affected by the nature of the inorganic ions present on the exchange complex. (5) Soil moisture: many herbicides are adsorbed more in dry than in wet soils. Vaporisation losses tend to be greater in wet than in dry soils. This may be related to changing solubility and competition with water molecules for exchange sites as soil moisture levels vary. (6) Effect of temperature: increasing temperature generally leads to a reduction in adsorption, partly because of effects on solubility and vapour pressure but also due to direct effects on adsorption/desorption. This effect would tend to coordinate maximum bioactivity with maximum plant uptake. (7) Nature of formulation: behavior and bioactivity of different formulations of a single herbicide vary greatly. Solvents, emulsifiers and surfactants drastically modify interaction between herbicide and soil. (8) Physical properties of soil as a substrate: pore size and pore space affect rate of movement of soil water and gaseous diffusion, both of which will affect adsorption/desorption. Soil colour will affect soil temperature. (9) Climatic factors: affects type of soil, soil moisture, and soil temperature. (10) Nature of soil water: rate of mass movement of water and rate of diffusion of herbicides in water differs between water in close proximity to a clay surface and water in the main pores. Thus, the physical state of soil water will have a considerable effect on herbicide bioactivity. 161 refs.

837. Wiese, A.F. and R.G. Davis. 1964. Herbicide movement in soil with various amounts of water. Weeds 12: 101-103.

There is a brief review of the literature on factors affecting the leaching of herbicides into and through soils. The penetration of 12 herbicides into 24" columns of silty clay loam top soil (Texas) was examined using a soybean bioassay. Herbicides were added to the columns in varying volumes of water with various post-application leaching treatments. Following treatment the cores were cut into 1.5" lengths for bioassay. Herbicides included an alkanolamine salt and a butoxy ethanol ester of 2,4-D, a triethylamine salt and a PGBE-ester of 2,4,5-%, silvex and its PGBE-ester, fenuron, monuron, PBA, 2,4,6-TBA, fenac and its butylcellosolve-ester. There was a general relationship between depth of penetration and water solubility except for water soluble amine salts of 2,4,5-T and silvex. These only leached to half the depth reached by amine salts of benzoic acids, apparently as the result of differential sorption by soil colloids. Leaching also varied with the method of application (volume of water) and the soil moisture (dry vs wet soils). The movement of herbicides which leach easily such as 2,3,6-TBA and PBA was less affected by these variables than less easily leached types. Esters of silvex, 2,4,5-T and 2,4,-D remained in the upper 3" of soil. Dimethylamine salts of 2,3,6-TBA and PBA were leached almost to the wetting front of descending water, while the rest were leached to intermediate depths. 20 refs.

838. Goring, C.A.I., C.R. Youngson and J.W. Hamaker. 1965. Tordon herbicide disappearance from soils. Down to Earth 20(4): 3-5.

Tordon (picloram) is widely and successfully used for control of brush, woody-rangeland and deep-rooted, perennial, herbaceous weed species. Its persistence and susceptibility to leaching through the soil has made it effective on deeply-rooted species. Picloram was applied at rates varying from 1.5-4.0 lbs/acre to agricultural soils in various U.S. states. The soils were sampled at 6" depths down to 54" at intervals varying from 4-41 months post application. Picloram was quantified in soil samples by bioassay using safflower. Peak concentrations were generally in the upper 12" of soil except where there were excessive amounts of irrigation. Losses in the first year varied from 58-96%; 78-100% within the second year. Data do not represent scientific experiments, so it is difficult to draw conclusions. Rather, the data result from a largely unreplicated, somewhat random monitoring of picloram residues over a variety of soils, application rates, geographic areas, and sampling periods. 6 refs.

839. Bailey, G.W. 1966. Entry of biocides into water-courses, pp.94-103, In: Proc. Symp. Agric. Waste Waters, Water Resources Center, Univ. of Calif., Davis Calif., Rept. 10.

There is a discussion of the factors affecting the movement of biocides into water bodies. The author contends that of the 6 factors implicated in determining the behaviour, fate and persistence of biocides in soils, movement and adsorption are the ones controlling the entry of biocides into water courses. The role of these two factors and of weather are reviewed. The status of current knowledge concerning mechanisms of overland flow is discussed. 74 refs.

840. Hamaker, J.W., C.A.I. Goring and C.R. Youngson. 1966. Sorption and leaching of 4-amino-3,5,6-trichloropicolinic acid in soils. pp. 23-37. In: Organic Pesticides in the Environment. Advances in Chem. Ser. No. 60.

The adsorption of 4-amino-3,5,6-trichloropicolinic acid by 10 soils varying in percentage organic matter from 0.2-44.3 was well correlated with organic matter; 2,4-D and 2,4,5-T behaved rather similarly. There was no clear correlation between sorption and percent clay, percent silt, or percent sand, but there was a good correlation between adsorption and pH. This was confirmed by examining the effect of varying the pH on the adsorption of the herbicides by the soils. Adsorption showed a marked relationship to pH as a result of the effect of pH on the ionisation and solution of the herbicide. A test of the efficiency of organic soil amendments, hydrated metal oxides, and clay minerals in adsorbing the herbicides indicated that steer manure and Fe_2O_3 behave most like soils and that organic matter and hydrated metal oxides are principally responsible for soil adsorption of herbicides. Rate of leaching of the herbicides through the 10 soils confirmed the sorption data. Maximum sorption was attained rapidly where hydrated metal oxides were involved, while maximum sorption by organic matter was reached only after a lengthy equilibration period. Investigation of sorption by clays led to the conclusion that they were largely unimportant, except if they had significant levels of metalic impurities. 7 refs.

841. Herr, D.E., E.W. Stroube and D.A. Ray. 1966. The movement and persistence of picloram in soil. Weeds 14:248-250.

Surface applications of picloram were made at rates varying from 2 to 64 oz/acre to 3 different agricultural soils: a dark-coloured, heavy-textured silt clay (an old lakebed); a well-drained, light-textured soil (developed from stratified sand and gravel); and a dark-coloured, medium-textured soil (developed from a calcaresous loam till). Soils were sampled at 6" depths down to 36" and bioassays (using Phaseolus vulgaris) determined the concentrations of picloram. After about 450 days maximum levels of picloram were found in the surface 6" for the medium and heavy-textured soils, and below the 24" level for the light-textured soil. Greenhouse studies indicated that soil organic matter was the most influential factor in retaining picloram against leaching and in the reduction of phytotoxicity. The quantity of precipitation was important in the rate of soil migration. The effect of soil texture could not be quantified since it was confounded with soil organic matter levels. Picloram was found to be dissipated more rapidly at low than at high application rates on all 3 soils. 13 refs.

842. Harris, C.I. 1967. Movement of herbicides in soil. Weeds: 15:214-216.

The movement of 28 herbicides in columns of two different soils (a silt clay loam and a sandy loam) was examined using oats as a bio-assay. Herbicides were introduced 1.75 inches from the bottom of 7 inch columns packed with soil. These were subirrigated for 3 days after which the columns were sliced longitudinally and oats grown at 1 inch intervals along the two halves. Data are presented on the relative mobilities of the various herbicides. 3 refs.

843. Bailey, G.W., J.L. White and T. Rothberg. 1968. Adsorption of organic herbicides by montmorillonite: role of pH and chemical character of absorbate. Soil Sci. Soc. Amer. Proc. 32:222-234.

The fate and behavior of herbicides in soil depends upon chemical decomposition, photochemical decomposition, microbial decomposition, volatolization, soil migration, plant uptake, and adsorption. Adsorption-desorption appears to directly or indirectly affect all other six factors and is therefore of major significance. This study examined adsorption by montmorillonite clay (1.0-0.2 ppm) at pH 3.35 and 6.80 of 23 commonly used herbicides from the following families: s-triazines, substituted ureas, phenylcarbonates, aniline, anilides, phenylalkanoic acids, benzoic acids, and picolinic acids. Conformity to the Freundlich adsorption equation was found for nearly all organic compounds for both the H-clay and the Na-clay systems. Regardless of chemical character, adsorption occurred to the greatest extent on the highly acid H-montmorillonite compared with the near-neutral Na-montmorillonite. Within a chemical family, the magnitude of adsorption is governed by the degree of water solubility, while differences between chemical families are related to the dissociation constant of the adsorbate. The adsorption of basic compounds by montmorillonite clay systems is principally dependent upon the surface acidity and not upon the pH of the bulk solution: the reverse is true for the absorption of acidic compounds. The surface acidity of montimorillonite appears to be 3-4 pH units lower than that of the bulk solution. Mechanisms for the absorption of basic and acidic compounds are discussed. 45 refs.

844. Dowler, C.G., W. Forestier and F.H. Tschirley. 1968. Effect and persistence of herbicides applied to soil in Puerto Rican forests. Weed Science 16:45-50.

Six herbicides were applied at three rates to three different forest types in Puerto Rico. The soils were an alluvial clay, a permeable, well-drained laterite derived from serpentine, and a poorly-drained clay loam. The vegetation on the three types was xerophytic, moist tropical forest, and tropical rain forest, respectively. Picloram, dicamba, bromacil, prometrone, diuron and fenac were applied in a randomised complete block design with three replications using a cyclone hand spreader. Persistence and soil penetration were measured in soil cores 3,6, and 12 months after application using cucumber (Cucumis satira L.) as a bioassay. Defoliation and succession were studied on plots for 2 years post-treatment. Highly significant correlations were obtained between defoliation and plant kill. Picloram was the most effective on all sites, while fenac and diuron were ineffective. Defoliation was greatest on the dry sites. The timing of defoliation was similar for all herbicides starting one month post-treatment and increasing slowly over the next 6-8 months. 3 months after application herbicides were found down to the 48" soil depth. Persistence of herbicides was greatest in the driest area and least in the wettest. Residues dissipated faster from the upper 12" of soil than at greater depths. Persistence after 1 year was in the order fenac prometone picloram diuron bromacil dicamba. Dissipation was not due to volatolisation or photodecomposition since sufficient rain fell on all sites to wash herbicides into the soil. Persistence increased with rate of application but was not correlated with effectiveness. Post-treatment secondary succession was more affected by precipitation and light intensity (i.e. degree of defoliation) than by the type of herbicide residue. 18 refs.

845. Phillips, W.M. 1968. Persistence and movement of 2,3,6-TBA in soil. Weed Science 16: 144-148.

2,3,6-TBA has a high initial phytotoxicity and persistence. There is a brief review on the conflicting literature concerning persistence and degradation of this herbicide. 2,3,6-TBA has been applied at rates of 16-20 lbs/acre to plots on a silty clay loam in Kansas from 1955-1965. Soil cores were taken to either 8ft. or 11ft. and divided up into 12 inch sections, each of which was bioassayed for 2,3,6-TBA using soybeans which were sensitive to 0.025 ppm by weight. Phytotoxic residues were found down to 11 ft. and the level of residues did not reflect time since application. Peak residue concentrations occurred at the 3-5 ft. level, with a tendency for greater residues resulting from fall than from spring and summer applications. There was considerable variation in persistence and penetration even between replicate cores on a single plot, and these could not be related to post-treatment weather. A rough estimate of 50% is given for the amount of the original application remaining, this level having persisted in the soil for 11 years. 12 refs.

846. Bachelard, E.P. and M.E. Johnson. 1969. A study of the persistence of herbicides in soil. Australian For. 33:19-24.

The favoured herbicides in Australian forestry are picloram and 2,4,5-T. This greenhouse study studied persistence of picloram and 2,4-D (Tordon 50D), and of 2,4,5-T each at two levels of application. The effects of leaching and soil sterilization (autoclaving) on persistence were examined. The soil was a 1:1 mixture of silty-loam and coarse sand and herbicides were detected using Pinus radiata D. Don seed germination and seedling survival as a bioassay. Germination (emergence) was much less affected than seedling establishment and survival; only 2,4,5-T reduced germination and then only at a 5 lb/acre application rate. This effect only lasted one month. All herbicide treatments affected survival for one month, while the effect of Tordon 50D was more persistent than the other treatments. All treatments affected the morphology of seedling cotyledons and hypocotyl, and in many seedlings this led to mortality. However, only in the case of Tordon 50D did the effect persist more than 2 months, and the secondary foliage and shoots were normal. Tordon effects persisted for at least 6 months. Soil sterilization produced no differences in persistence. It is concluded that Tordon 50D will retain its toxicity for an extended period, but since its effects are chiefly to cotyledons and hypocotyls this should not pose a problem for radiata pine seedlings planted a few months after herbicide application. 1 ref.

847. Bovey, R.W., C.C. Dowler and M.G. Merkle. 1969. The persistence and movement of picloram in Texas and Puerto Rican Soils. Pesticides Monitoring Journal 3(3): 177-181.

Picloram is an effective control agent for woody tropical and non-tropical species. Higher rates are required for woody than perennial weeds. Picloram tends to be very persistent, microbial and chemical decomposition being very slow. Leaching and photodecomposition are important factors controlling residue levels. The loss of picloram was studied from 2 soils (clay loam and sand) in Texas and 3 soils (lateritic clay derived from serpentine, a calcareous clay, and a poorly drained sand) in Puerto Rico. K salt of picloram was applied at 1,3 and 9 lbs/acre. Cucumber (Cucumis sativus L.) was used as a bioassay. Gas chromotography was used to analyse some of the samples. Treated soils were sampled at 12" depths to 48" for 12-18 months post-treatment. Picloram was most persistent in the clay soil where the rainfall was lowest, and was least persistent in sandy soils where rainfall was highest. It was thought that there was some lateral movement of picloram. It was concluded that the study was unable to account for all of the herbicide applied. 23 refs.

848. Doherty, P.J. and G.F. Warren. 1969. The adsorption of four herbicides by different types of organic matter and a bentonite clay. Weed Res. 9:20-26.

This study attempts a direct comparison of the biological significance of herbicide adsorption by organic matter and clay (bentonite). The herbicides used were prometoyne, simazine, linuron and pyrazon and the bioassay species was sugar beet or Indian mustard. The technique required a 2 week assessment period since these herbicides are photosynthetic inhibitors. The plants were grown in quartz plus 1% of bentonite, sphagnum moss, fibrous peat, or muck soil at various levels of herbicide to find the level causing 50% growth inhibition. Peat and muck adsorbed much more than sphagnum or bentonite, the latter having the lowest adsorptive capacity, scarcely above that of quartz sand. A comparison of the adsorption of prometryne on 6 soils varying in organic matter by a factor of 55 gave a variation of 30-

fold. It is concluded that organic matter is very much more significant in the adsorption of herbicides by soil than clay; that organic matter varies in its sorptive efficiency although this difference cannot be explained simply by cation exchange and hygroscopic surface. It appears that the chemical rather than the physical properties of the organic matter are important in explaining variations in adsorption. There was no general relationship between sorption and solubility, but this is not expected between different chemical formulae. 19 refs.

849. Norris, L.A. 1970. The kinetics of adsorption and desorption of 2,4-D, 2,4,5-T, picloram, and amitrole on forest floor materials. Res. Prog. Dept. Western Soc. Weed Sci. 1970: 103-105.

Air dried 10-50 mesh forest floor from a red alder (Alnus rubra Bong.) stand was buffered (pH 6.5 using potassium phosphate) and mixed with 14 C-labeled solutions of 2,4-D, 2,4,5-T, picloram, or amitrole. At equilibrium (30°C) the following % adsorptions were observed: 27% for picloram, 34% for 2,4-D, 61% for 2,4,5-T, and 72% for amitrole. Time to reach equilibrium varied with herbicide and with temperature. Adsorption and desorption occurred at the same rates for 2,4-D and 2,4,5-T but varied for picloram and amitrole. No refs.

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An annotated bibliography of 80 articles published in the period 1967-1968 on the topic of the persistence and decomposition of herbicides in soils and plants. 80 refs.

851. Anon. 1971. Bibliography on persistence and decomposition of herbicides in soils and plants (1971-1969). Serial No. 1477, Commonwealth Bureau of Soils, Harpenden, England, 27 p.

An annotated bibliography of 106 articles published in the period 1969-1971 on the topic of the persistence and decomposition of herbicides in soils and plants. 106 refs.

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The interactions of organic pesticide with particulate matter in surface waters and soil systems are discussed in relation to the chemical properties of the compounds and their reported behavior in these systems. The types of particulate matter discussed include clay minerals, soil organic matter, charcoal. The pesticides are

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B. Effects on soil microorganisms

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This laboratory study examined the effects of dinitro-o-secondary butyl phenol, ortho-chlorophenol-sulfonyl fluoride, sodium 2,4-dichlorophenoxyethyl sulfate, CMU, and IPC on respiration rates and plate counts. Plots of undetermined size were each treated with one of the herbicides; soil samples were taken after one and three months. To determine respiration rates each sample was divided into two parts. One part had water added while the other had water and glucose added. The difference between these two was designated as the respiration rate. After 1 month, only dinitro-o-secondary butyl phenol, ortho-chlorophenol-sulfonyl fluoride, and CMU inhibited respiration; after 3 months, only dinitro-o-secondary butyl phenol and ortho-chlorophenol-sulfonyl fluoride did so. Plate counts were done using soil-extract agar with glucose added. All the herbicides tested affected plate counts after 1 month. However, after 3 months, only dinitro-so-secondary butyl phenol and ortho-chlorophenol-sulfonyl fluoride had any effect. 7 refs.

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The effect of simazine and atrazine on carbon dioxide production, nitrate production, and bacterial and fungal numbers was examined using fine, air-dried sand with calcium carbonate, cottonseed meal, and 15% water added. High concentrations of these triazines were necessary to produce any effects: carbon dioxide production was not affected by the range of concentrations tested (up to and including 8192 ppm); nitrate production was affected by 1024 ppm and greater of atrazine and 2048 ppm and greater of simazine; no effect on bacterial or fungal numbers was discernible although 64 ppm was the highest concentration examined. Several pure microbial cultures were tested; no significant inhibition was noticed at concentrations below 256 ppm. With some stationary pure cultures a stimulatory as well as inhibitory response was noted at some concentrations. However when one such culture was tested in a shaker, no stimulation of growth was evident. 1 refs.

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A bean bioassay was used to examine the effect of Aspergillus niger cultures on 2,4-D and picloram. The growth of the cultures treated with these two herbicides was also examined. Growth of the fungus was significantly reduced at 10 and 50 ppm by weight of 2,4-D, but it reduced the phytotoxicity of this herbicide at these

concentrations. Picloram at rates up to 50 ppm did not reduce fungus growth. It was also degraded by the fungus, but not as much as 2,4-D. Both herbicides were accumulated in the fungus mycelium. 3 refs.

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C. Effects on soil fauna

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IV. HERBICIDES, HYDROLOGY, AND AQUATIC ECOSYSTEMS

A. Effects on water quality

1019. Faust, S.D. and O.M. Aly. 1963. Some effects of 2,4-dichlorophenoxyacetic acid and 2,4-dichlorophenol on drinking water quality. 17th Northeastern Weed Contr. Conf., 10 p.

The paper describes experiments in which the persistence of 2,4-D and 2,4-DCP was examined (occurring as an impurity) in either tap or lake water stored in carboys at room temperature. The effects of anaerobic conditions and of the addition of organic matter in the form of sewage was investigated. The study was concerned with the effect of these materials on taste and odour as they affect the quality of drinking water. Concentrations as low as 2 micrograms/litre can be detected by taste and odour. It was found that concentrations high enough to affect odour levels persisted for at least 218 days. This was reduced to 59 days in the presence of decomposing organic material. Under stable neutral pH and aeration, 50% of 2,4-DCP is removed from lake waters in 6 days. Under acid anaerobic conditions 40-50% of the original material can persist for up to 80 days. 5 refs.

1020. Aly, O.M., and S.D. Faust. 1964. Studies on the fate of 2,4-D and ester derivatives in natural surface waters. Agric. and Food Chem. 12: 541-546.

The paper reports a series of experiments into physical, chemical and biological factors affecting the persistence and degradation of 5 formulations of 2,4-D. Sorption by bentonite, ilite, and kaolinite clays was found to be insignificant. Formation of salts with Ca and Mg was not found to remove 2,4-D from solution because of the high solubility of these salts. Ultraviolet photolysis occurred and was found to be pH dependent: it occurred faster at pH 9.0 than at pH 7.0 or 4.0. However, ultraviolet energies in sunlight are too low to duplicate the laboratory photolysis. 2,4-D was decomposed (80-85%) within 24 hours by bottom mud containing 2,4-D-adapted flora: it disappeared completely in 65 days from untreated lake mud. 2,4-D persisted up to 120 days in lake water aerobically incubated in laboratory. 19 refs.

1021. Norris, L.A., M. Newton and J. Zavitkovski. 1966. Stream contamination with amitrole following brush control operations with amitrole-T. Res. Prog. Repts. Western Weed Control Conf. 1966, p. 20-22.

Contamination of streams in Oregon as the result of spraying salmonberry with amitrol-T was studied. Concentrations as high as 400 ppb were found 5 minutes after treatment immediately downstream from treated areas. This decreased to zero after 72 hours. One mile downstream there was virtually no detectable contamination. This was ascribed to dilution and adsorption onto colloids and stream organic matter.

1022. Averitt, W.K. 1967. Report on the persistency of 2,4-dichlorophenoxyacetic acid and its derivatives in surface waters when used to control aquatic vegetation. Univ. S.W. Louisiana, Lafayette, La.

A series of studies are described which were conducted on the effectiveness and persistence of 2,4-D and diglycolic acid against alligatorweed in tanks and ponds in S.E. United States. The effect of pH on certain herbicides under both hot and cold climatic conditions was studied experimentally using molasses to lower the pH. The addition of molasses prolonged the disappearance of the herbicide by only a few days under warm conditions, but was correlated with a significant delay under cold conditions. 7 refs.

1023. Barnett, A.P., E.W. Hauser, A.W. White and J.H. Holladay. 1967. Loss of 2,4-D in washoff from cultivated fallow land. Weeds 15: 133-137.

The study was undertaken to get quantitative data on the movement of various formulations of 2,4-D in "washoff" (defined as the water-soil mixture resulting from the combination of surface runoff and eroding soil). Three different formulations were used: iso-octyl ester, propylene glycol butyl ester, and alkanolamine salt of the ethanol and isopropanol series. Applications were made to a cultivated fallow sandy loam soil, and simulated rainfall approximating 1, 10, 80 and 100 year storm intensities and durations was used to produce washoff. Herbicide movement was bioassayed using cucumber seedling root length. The amino salt was most resistant to washoff, less than a third as much being lost in a one-year frequency storm as compared with the esters; less than one fifth as much was lost for a 100 year storm. Most of the 2,4-D remained in the surface three inches of soil, however, irrespective of formulation. 8 refs.

1024. Frank, P.A. and R.D. Comes. 1967. Herbicidal residues in pond water and hydrosoil. Weeds 15: 210-213.

Dichlobenil, fenac, 2,4-D, paraquat, diquat and endothal were applied to 8 ponds as either liquid or granular applications, and samples of hydrosoil and water were taken at intervals to study the persistence of the herbicides. Relatively high concentrations of dichlobenil, fenac and 2,4-D were present in the upper one inch of soil following applications of granular formulations. The former two persisted in soil and water for more than 160 days which 2,4-D decreased to very low levels in the water after 36 days and in the soil after 85 days. Endothal, paraquat and diquat were less persistent in water and were not found after 24, 8 and 4 days, respectively. Paraquat and diquat persisted in the soils for 85 and 160 days, respectively. In ponds with dense weed infestations, a large fraction of the herbicide may be held by plants for some time. 6 refs.

1025. Norris, L.A. 1967. Chemical brush control and herbicide residues in the forest environment. pp. 103-123, In: Herbicides and Vegetation Management in Forests, Ranges and Noncrop Lands. Proc. Symp. Oregon State Univ., Corvallis.

The fate of herbicide applications to the forest environment is reviewed. Drift and volatolization can result in considerable losses (example of 25-75% are quoted). Of the herbicide which is intercepted by vegetation, most will be transferred to the forest floor by the leaf or into the stem. The fate of various brush-control herbicides in the forest floor is discussed and data on rates of disappearance from the forest floor are presented. This parameter is of importance since it affects stream contamination by the herbicide, such contamination being the most important polluting aspect of herbicides. Data are presented from experiments examining stream contamination by 2,4-D, 2,4,5-T, and amitrole following helicopter spraying of brush areas in Oregon. In some cases the sprayed areas included active streams. It was concluded that some herbicides will appear in nearly all streams which flow by or through treated areas, but that most of this results from direct application to the streams and is therefore short lived. Short lived concentration peaks were very much less than LD_{50} data for fish and mammals, but in some cases concentrations exceeded for a short period the concentration at which some biological affects may have occurred (100 ppb). 8 refs.

1026. Tarrant, R.F. and L.A. Norris. 1967. Residues of herbicides and diesel oil carriers in forest waters: a review. pp. 94-102. In: Herbicides and Vegetation Management in Forests, Range and Noncrop Lands. Proc. Symp. Oregon State Univ., Corvallis.

The chief environmental problem of herbicide use is said to be water pollution. The paper reviews studies which suggest that the only stream contamination from spraying brushlands with 2,4-D, 2,4,5-T or amitrole occurs a few hours after spraying. Levels of 2,4-D and 2,4,5-T drop below detection limits (0.5 ppb) within a few days. Amitrole levels in streams dropped from 400 ppb 5 minutes after spraying to 4 ppb after 10 minutes. Heavy rain storms may induce temporary post-treatment increases (10 ppb). Studies are cited to support the claim that these levels do not have a "substantial" impact on stream bottom fauna and salmon fry. The importance of the chemical formulation of herbicides is discussed. Lack of more serious stream contamination problems is ascribed to rapid biological degradation of these herbicides as shown in laboratory studies. Diesel oil carrier is similarly held and degraded in the upper soil layers and the literature on this topic is reviewed. It is concluded, however, that while much of the available literature minimises the problems of stream contamination, the broad ecological implications of brush removal must be considered and it should be remembered that much existing information is from studies conducted before there was a full recognition of the potential dangers associated with herbicide use. 35 refs.

1027. Davis, E.A., P.A. Ingebo and C.P. Pase. 1968. Effect of a watershed treatment with picloram on water quality. USDA For. Serv. Res. Note RM-100, 4 pp.

Picloram was applied in pellet form to a watershed in Arizona for control of chaparral brush. Streamwater was analysed at irregular intervals. Concentrations as high as 0.35 ppm were observed as long as 70 days after application, high levels always being associated with periods of heavy rain. After 16 months and 40 inches of accumulated rain picloram was not detected in the streamwater. It was concluded that while picloram is highly susceptible to soil leaching in the soils in the study watershed, concentrations toxic to animals were not observed in the streamwater. However, the water would have had an effect on some plants and would not have been suitable for irrigation purposes during periods of high concentration. 17 refs.

1028. Norris, L.A. 1968. Stream contamination by herbicides after fall rains on forest land. Res. Prog. Rept., Western Soc. Weed Sci. 1968, p. 33-34.

This study showed that fall rains do not result in appreciable contamination of streams flowing through forested areas treated with phenoxy or amitrole herbicides in spring or early summer.

1029. Reigner, I.C., W.E. Sopper and R.J. Johnson. 1968. Will the use of 2,4,5-T to control streamside vegetation contaminate public water supplies? J. For. 66: 914-918.

Riperian vegetation along two small streams in Pennsylvania and New Jersey were treated with 2 formulations of 2,4,5-T using a mist-blower. Water samples were collected immediately and periodically thereafter and subjected to an odor test. Only slight contamination occurred immediately after treatment and the first major rain storms, and only in the treated area: no contamination was detected downstream. 13 refs.

1030. Trichell, D.W., H.L. Morton, and M.G. Merkle. 1968. Loss of herbicides in runoff water. Weed Sci. 16: 447-449.

Dicamba, 2,4,5-T and picloram were applied to a clay loam soil with and without a sod cover. Plots were watered and surface runoff collected 24 hours and 4 months after treatment. The relative losses of the different herbicides varied between the sod and the fallow plots. The slope of the plot and movement over untreated soil influenced the per cent of picloram lost. The maximum loss from the plots of any herbicide was 5.5% of that applied and the average was about 3%. The amount of herbicide in the surface flow varied according to application rate, but was proportional to the application rate. 5 refs.

1031. Averitt, W.K. 1969. Persistency and residue of 2,4-Dichlorophenoxyacetic acid in surface waters when used to control alligatorweed. Chem. Eng. Dept. Univ. S.W. Louisiana, Lafayette, La. 93 pp.

A continuation of earlier work, this study involved application of 2,4-D to alligatorweed in 12 foot tanks and in the field to study persistence, decomposition in solution, and uptake and translocation. 8 refs.

1032. Douglass, J.E., D.R. Cochrane, G.W. Bailey, J.I. Teasley, and D.W. Hill. 1969. Low herbicide concentration found in streamflow after a grass cover is killed. USDA For Serv. Res. Note. SE-108, 3p.

The grass cover on a steep Appalachian watershed was sprayed initially with atrazine and paraquat, and later with atrazine and 2,4-D. The initial spray included water courses. Water samples were taken weekly and analysed for herbicides. Maximum concentrations of paraquat were 19 ppb; none was detected a month after application. No contamination was found in streams after the second application which left a 10 foot strip unsprayed each side of water courses. 7 refs.

1033. Norris, L.A. 1969. Herbicide runoff from forest lands sprayed in summer. Res. Prog. Rept., Western Weed Soc. p. 24-26.

The movement of picloram and phenoxy herbicides into streams as the result of summer spraying was studied in Oregon and Washington. The greatest potential problem occurs when early fall storms are sufficiently intense to cause overland flow rather than infiltration. The amount of stream contamination is largely determined by the proportion of the watershed that is treated. The maximum level of 2,4-D observed was 825 ppb, declining to 250 ppb after 9 days and one ppb after about 7 weeks. The highest value for picloram was 78 ppb declining to 38 ppb in 9 days and 1 ppb after about 8 weeks.

1034. Bailey, G.W., A.D. Thurston Jr., J.D. Page Jr., and D.R. Cochrane. 1970. The degradation kinetics of an ester of silvex and the persistence of silvex in water and sediment. Weed Sci. <u>18</u>: 413-418.

The PGBE ester of silvex, a herbicide used in the control of noxious aquatic weeds in waterways, was applied to 3 small ponds in Louisiana, and water and sediment samples collected at frequent intervals for the following 7 weeks. Hydrolysis of the ester to silvex obeyed first order reaction kinetics. 50% hydrolysis occurred in 5-8 hours, 90% in 16-24 hours. The concentration of silvex in the water initially increased but decreased to zero by the end of 3 weeks as the result of adsorption of both the PGBE ester and silvex by the sediment. Silvex adsorption by the sediments conformed to the Freundlich adsorption equation under laboratory conditions. Gas chromatography was used to determine silvex and its ester. 35 refs.

1035. Davis, E.A. and P.A. Ingebo. 1970. Fenuron contamination of stream water from a chaparral watershed in Arizona. Res. Prog. Rept. West. Weed Soc. p. 22-23.

Treatment of mixed chaparral along the major stream channels of an Arizona watershed resulted in low levels of fenuron in the water for as long as 2 years. Levels as high as 0.43 ppm was measured 33 days after treatment following heavy rains. 2.4% of the applied fenuron left the watershed during the 27 months after treatment.

1036. Grzenda, A.R. 1963. Public health aspects of weed control in potable water supplies. Proc. So. Weed Conf. 16: 420-424.

1037. McKee, J.E. and H.W. Wolf. 1963. Water quality criteria, 2nd Ed. The Resources Agency of California, State Water Quality Control Board, 367 pp.

1038. Bruns, V.F. and R.R. Yeo. 1964. Tolerance of certain crops to several aquatic herbicides in irrigation water. USDA, Agr. Exp. Stations of Washington, Montana and Arizona, Technical Bull. 1299.

1039. Coates, G.E., H.H. Funderburk, Jr., J.M. Lawrence, and D.E. Davis. 1964. Persistence of dequat and paraquat in pools and ponds. Proc. Southern Weed Conf. 17: 308-320.

1040. Krammes, J.S., and D.B. Wellets. 1964. Effects of 2,4-D and 2,4,5-T on water quality after a spraying treatment. U.S. Forest Service, Research Note PSW-52, 4 pp.

1041. Nicholson, H.P., and J.R. Thoman. 1965. Pesticide persistence in public water, their detection and removal. In: Research in Pesticides. Academic Pres,, Inc., New York. pp. 181-189.

1042. Grzenda, A.R., H.P. Nicholson, and W.S. Cox. 1966. Persistence of four herbicides in pond water. J. Am. Water Works Assoc. 58: 326-332.

1043. Hayes, W.J., Jr. 1966. Monitoring food and people for pesticide content. In: Scientific Aspects of Pest Control. Nat. Acad. Sci., Nat. Res. Connc., Publ. 1402, pp. 314-342.

1044. Sopper, W.E., I.C. Reigner, and R.R. Johnson. 1966. Effect of phenoxy herbicides on riparian vegetation and water quality. Weeds Trees and Turf. 1966:

1045. Weibel, S.R., R.B. Weidner, J.M. Cohen, and A.G. Christianson. 1966. Pesticides and other contaminants in rainfall and runoff. J. Amer. Water Works Assoc. 58: 1075-1084.

1046. Aldhous, J.R. 1967. 2,4-D residues in water following aerial spraying in a Scottish forest. Weed Res. 7: 239-241.

1047. Averitt, W.K. 1967. An evaluation of the persistence of 2,4-D amine in surface waters in the state of Louisiana. Proc. So. Weed Conf. 20: 342-347.

1048. Brown, E., and Y.A. Nishioka. 1967. Pesticides in selected western streams - A contribution to the national program. Pest. Moni. J. 1: 38-41.

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1051. Kochkin, V.P. 1967. Experimental data for the hygienic standardization of the dalapon level in bodies of water. Gig. Sanit. 32: 7-11.

1052. Norris, L.A., M. Newton, and J. Zavitkovski. 1967. Stream contamination with amitrole from forest spray operations. Western Weed Control Conf. Res. Prog. Rept. 1967: 33-35.

1053. Tarrant, R.F. 1967. Pesticides in forest waters -- Symptom of a growing problem. Soc. Amer. Forest. Proc. 1966: 159-163.

1054. Marston, R.B., D.W. Schultz, T. Shiroyama, and L.V. Snyder. 1968. Amitrole concentrations in creek waters downstream from an aerially sprayed watershed sub-basin. Pestic. Monit. J. 2: 123-128.

1055. Anon. 1969. Side effects of Chemicals: basal bark applications of 2,4,5-T in diesel oil and water supplies. Rep. For. Res. For. Comm., Lond. 1968/1969: 80,82-3.

1056. Haas, R.H., C.J. Scifres, M.G. Merkle, R.R. Hahn, and G.O. Hoffman. 1971. Occurrence and persistence of picloram in grassland water sources. Weed Res. 11 (1): 54-62.

Cross references: 558, 707, 721, 755, 758, 771, 773, 815, 839, 852, 911, 952, 956, 957, 1066, 1082, 1137, 1162, 1164, 1428, 1444

B. Effects on quantity of water

1057. Tarrant, R.F. 1957. Soil moisture conditions after chemically killing manzanita brush in Central Oregon. U.S. Forest Service, PNW Forest and Range Expt. Sta. Res. Note 156. 4pp.

The effects of either chemically killing or chemically killing and removing manzanita brush on the moisture levels was examined in a loamy coarse sand or pumicy loamy coarse sand in central Oregon. Both the treatments greatly reduced the normal depletion of soil moisture which occurs under green manzanita brush. The significance of this for ponderosa pine regeneration is noted.

1058. Army, T.J., A.F. Wise, and R.J. Hanks. 1961. Effect of tillage and chemical weed control practices on soil moisture losses during the fallow period. Proc. Soil Sci. Soc. Amer. 25: 410-413.

Maintenance of surface residues in agricultural areas of the Great Plains by stubble-mulch tillage or chemical weed control was shown to significantly reduce drying and maintain soil moisture in the surface two inches of soil. 15 refs.

1059. Sonder, L.W., and H.P. Alley. 1961. Soil-moisture retention and snow-holding capacity as affected by the chemical control of big sage-brush (Artemisia tridentata Nutt.) Weeds 9: 27-35.

Areas of sagebrush were sprayed at two locations in Wyoming using 2,4-D formulations. Soil moisture surveys were conducted on the treated and control areas after one year and six years. Snow surveys were conducted the two years following treatment. Significantly higher soil moisture percentages were recorded on treated than on control areas both one and six years after chemical control of the sagebrush. In areas where snow drifting occurs chemical brush control did not affect snow retention. On one of the areas, snow was held for longer in the spring as the result of chemical treatment, however. 9 refs.

1060. Heidmann, L.J. 1969. Use of herbicides for planting site preparations in the southwest. J. For. 67 (7): 506-509.

A comparison was made of the effects of mechanical scalping and chemical (dalapon) control of vegetation in the ponderosa pine region of Arizona on soil moisture. Both methods conserved soil moisture, but the herbicide treatment was more effective, especially in the critical upper layers (0-8"). The superiority of the chemical treatment is ascribed to the mat of dead grass which served as a mulch to reduce evaporation, soil heating, and runoff. The herbicide treatment produced a more persistent effect than the mechanical method. No refs.

1061. Elwell, H., W.E. McMurphy, and P.W. Santelmann. 1970. Burning and 2,4,5-T on post and blackjack oak rangeland in Oklahoma. Oklahoma State Univ., Agr. Exp. Sta. Bull. No. B-675, 11 pp.

The objective of this study was to examine the effects of herbicides plus controlled burning upon soil moisture levels and control of woody plant control and increased sprouting of many woody species. Without herbicides there was insufficient fuel for a hot fire. Use of 2,4,5-T increased the yield of herbaceous vegetation providing more fuel and a hotter fire. Fire plus herbicides resulted in an immediate increase in annual weeds which were subsequently replaced by perennial grasses. Soil moisture was significantly increased whenever 2,4,5-T was used. Burning also increased soil moisture but less than the herbicide. It is inferred that the woody species controlled by the herbicide are major users of soil water. 12 refs.

1062. Wiese, A.F., and T.J. Army. 1958. Effect of tillage and chemical weed control practices on soil moisture storage and losses. Agron. J. 50: 465-468.

1063. Wiese, A.F., and T.J. Army. 1960. Effect of chemical fallow on soil moisture storage. Agron. Jour. 52: 612-613.

1064. Merriam, R.A. 1961. Saving water through chemical brush control. J. Soil Water Conservation 16: 84-85.

1065. Reinhart, K.G. 1965. Herbicidal treatment of watersheds to increase water yield. Proc. Northeastern Weed Control Conf. 19: 546-551.

1066. Pierce, R.S. 1969. Forest transpiration reduction by clearcutting and chemical treatment. Abstr. Proc. 23rd Ntheast. Weed Control Conf. 23: 344-9.

1067. Brown, H.E. 1970. Status of pilot watersheds in Arizona. Journal of the Irrigation and Drainage Division, Proc. of the Amer. Soc. of Civil Engineers 96 (IR·1): 11-23.

1068. Lynch, J.A., and W.E. Sopper. 1970. Water yield increased from partial clearcutting of forested watershed. Sci. Agric. 17 (3): 8-9.

1069. Sopper, W.E., and J.A. Lynch. 1970. Changes in water yield following partial forest cover removal on an experimental watershed. Penns. State Univ., Inst. Research Land and Water Resources, Reprint Series No. 21. 21 pp.

Cross references: 102, 279, 317, 768, 1070

C. Effects on hydrological processes

1070. Ursic, S.J. 1970. Hydrologic effects of prescribed burning and deadening upland hardwoods in northern Mississippi. U.S. For. Serv. Res. Pap. 5th For. Exp. Sta. No. 50-54. 15 pp.

Cross references: 1059, 1431

D. Effects on water fauna and flora

1071. Hardy, J.L. 1966. Effect of Tordon herbicide on aquatic chain organisms. Down to Earth 22 (2): 11-13.

Guppies and daphnia were reared in water containing sub-lethal levels of Tordon 22K (picloram) and studies were made of food chain concentration (water algae daphnia guppies) and effects on fish reproduction. The daphnia reared at 1 ppm acid equivalent of Tordon apparently developed and reproduced normally over a 10 week period. Guppies kept in water at 1 ppm and fed daphnia reared at 1 ppm concentration appeared to be normal in development, behaviour and reproduction. Concentrations of 1 ppm acid equivalent of Tordon did not retard the growth of algae, nor did it inhibit the feeding of daphnia on the algae.

1072. Mullison, W.R. 1970. Effects of herbicides on water and its inhabitants. Weed Sci. 18 (6): 738-750.

There is an extensive review of the effects of a considerable variety of herbicides on aquatic organisms. It is concluded that there is little evidence of herbicides from agronomic or industrial usage reaching or accumulating in water supplies in amounts necessary to cause a pollution problem. At the present state of knowledge, harmful effects of herbicides on fish, plankton and other aquatic organisms are only temporary. Available evidence suggests that there is no biological magnification problem with herbicides. 150 refs.

1073. Greulach, V.A., J. McKenzie, and E.M. Stacy. 1951. The effect of maleic hydrazide on the embryonic and larval growth of three amphibians. Biol. Bull. 101: 285-288.

1074. Beaven, G.F., C.K. Rawls, and G.E. Beckett. 1962. Field observations upon estuarine animals exposed to 2,4-D Northeastern Weed Control Conf., Proc. Suppl. 16: 449-458.

1075. Tatum, W.M., and R.D. Blackburn. 1962. Preliminary study of the effects of diquat on the natural bottom fauna and plankton in two subtropical ponds. S.E. Asoc. Game Fish. Comm. Ann. Conf., Proc. 16: 301-307.

1076. Harp, G.L., and R.S. Campbell. 1964. Effects of the herbicide silvex on benthos of a farm pond. J. Wildlife Manage. 28: 308-317.

1077. Cowell, B.C. 1965. The effects of sodium arsenite and silvex on the plankton populations in farm ponds. Trans. Amer. Fish. Soc. 94: 371-377.

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1079. Steenis, J.H., et. al. 1965. Effects of eurasian watermilfoil control procedures on waterfowl and other organisms in aquatic environments. In: Effects of pesticides on fish and wildlife. Fish and Wildlife Service, Circular 226, p. 10.

1080. Rawls, C.K. 1966. Providing estuarive fauna for residue analysis of field-applied herbicides. Univ. of Maryland, Natural Resources Institute, Chesapeake Biol. Lab (Solomons, Maryland), Project 66-7.

1081. DeVaney, T.E. 1967. Chemical Vegetation Control Manual for Fish and Wildlife Management Programs. USDI, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Washington, D.C., GPO 926-794, 42 pp.

1082. Smith, G.E., and D.G. Ison. 1967. Investigation of effects of largescale applications of 2,4-D on aquatic fauna and water quality. Pestic. Monit. J. 1 (3): 16-21.

1083. Sanders, H.O., and O.B. Cope. 1968. The relative toxicities of several pesticides to naiads of three species of stoneflies. Limnol. Oceanogr. 13: 112-117.

1084. Sanders, H.O. 1969. Toxicity of pesticides to the crustacean, Gammarus lacustris. Tech. Paper 25, Bur. Sport Fish. Wildl., U.S.D.I., 18 pp.

1085. Vance, B.D., and D.L. Smith. 1969. Effects of five herbicides on three green algae. Tex. J. Sci. 20: 329-337.

1086. Sanders, H.O. 1970. Pesticide toxicities to tadpoles of the western chorus frog, Pseudacris triseriata, and Fowler's toad, Bufo woodhousii fowleri. Copeia 2: 246-251.

Cross references: 558, 632, 637, 721, 771, 815, 1026, 1395, 1402, 1408, 1413, 1420, 1422, 1430, 1435, 1436, 1461.

V. HERBICIDES AND PLANTS

A. Effects on plant physiology

1087. Funderburk, H.H., Jr. and J.M. Lawrence. 1964. Mode of action and metabolism of diquat and paraquat. Weeds 12: 259-264.

Warburg studies were conducted on the effect of diquat and paraquat on respiration in duckweed. Similar studies of the effect of diquat, paraquat, monuron and atrazine on photosynthesis in duckweed were also undertaken. The degradation of ^{14}C-labeled diquat and paraquat by beans and alligator weed is reported. Both diquat and paraquat stimulated respiration and inhibited photosynthesis in duckweed. Atrazine and monuron inhibited the Hill reaction at lower concentrations ($10^{-6}M$) than diquat and paraquat, however. The effect on O_2 production of combining monuron and diquat was additive. The degree of inhibition of the Hill reaction was related to the redox potential of the herbicides. Neither alligator weed nor beans effected any degradation of diquat or paraquat. 31 refs.

1088. Conner, B.J., and D.P. White. 1968. Triazine herbicides and the mineral nutrition of conifers. In: Tree Growth and Forest Soils, Proc. 3rd N. American For. Soils Conf., Oregon State Univ., Corvallis, pp. 193-204.

Simazine and atrazine have been widely used to control weeds in tree plantations. The paper reviews evidence that low levels of simazine result in higher foliar nitrogen levels, higher water extractable protein, higher respiration rates, lower carbohydrate accumulation rates, and lower dry weight production. Most of this evidence refers to agricultural plants: this paper examines the effects of simazine and atrazine on the nutrition of slash pine growing in sandy soil in a controlled environment and of Scotch pine, white spruce and balsam fir nursery stock planted on a sandy loam. Atrazine, simazine, woodchip mulch, and amonium nitrate were applied as treatments in various combinations. Plots not receiving the triazines were treated with chlordane, Amitrol-T, and paraquat to reduce vegetative compeition. Simazine was found to enhance accumulation of nitrogen in the 3-month-old slash pine seedlings but reduced top growth and total nitrogen uptake. Applied as a pre-emergent to the field-planted nursery stock, simazine did not significantly alter foliar nitrogen concentrations. Fertilizer added to simazine-treated plots did not increase foliar nitrogen concentrations. Simazine tended to reduce foliar phosphate concentrations and also produced needle cast and death in the spruce nursery stock. 12 refs.

1089. Reid, C.P.P., and W. Hurtt. 1970. Root permeability as affected by picloram and other chemicals. Physiologia Plantarum 23: 124-130.

The effects of several herbicides on root permeability were studied by means of betacyanin efflux from red beet root sections. Picloram in the 10^{-3}M to 10^{-6}M range had no effect. Dicamba, low levels of 2,4-D, and ethylene produced similarly negative results. PMA, DNP and 2,4,5-T and higher levels of 2,4-D did cause significant pigment leakage, however. In a separate experiment with bean plants, it was found that picloram had no effect on root cell membrane integrity, that it did not act as a metabolic inhibitor in the root system, and that it stimulated salt secretion into the xylem. 16 refs.

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1091. Friberg, S.R., and H.E. Clark. 1952. Effects of 2,4-dichlorophenoxyacetic acid upon the nitrogen metabolism and water relations of soybean plants grown at different nitrogen levels. Bot. Gaz. 113: 322-333.

1092. Rhodes, A. 1952. The influence of the plant growth regulator 2-methyl-4-chlorophenoxyacetic acid, on the metabolism of carbohydrate, nitrogen and minerals in Solanum lycopersicum (tomato). J. Exp. Bot. 3: 129-154.

1093. French, R.C., and H. Beevers. 1953. Respiratory and growth responses induced by growth regulators and allied compounds. Amer. J. Bot. 40: 660-666.

1094. Fang, S.C., and J.S. Butts. 1954. Studies in plant metabolism. IV. Comparative effects of 2,4-dichlorophenoxyacetic acid and other plant growth regulators on phosphorus metabolism in bean plants. Plant Physiol. 29: 365-368.

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1096. Woods, F.W. 1955. Control of woody weeds: some physiological aspects. Southern For. Expt. Sta. Occas. Paper 143.

1097. Cooke, A.R. 1956. A possible mechanism of action of the urea type herbicides. Weeds 4: 397-398.

1098. Minshall, W.H. 1957. Influence of light on the effect of 3-p-(chlorophenyl)-1, 1-dimethylurea on plants. Weeds 5 (1): 29-33.

1099. Palmer, R.D., and W.K. Porter. 1959. The metabolism of nut grass (Cyperus rotundus L.) IV. The activities of certain enzymes from tubers treated with amitrol. Weeds 7: 511-517.

1100. Ingle, M., and B.J. Rogers. 1960. Some physiological effects of 2,2-dichloropropionic acid. Weeds 9: 264-272.

1101. Minshall, W.H. 1960. Effect of 3-(4-chlorophenyl)-1, 1-dimethylurea on dry matter production, transpiration, and root extension. Can. J. Botany 38: 201-216.

1102. Rogers B.J. 1960. Physiological characteristics of herbicides. In: Herbicides and their use in forestry, R.E. McDermott and W.R. Byrnes, eds., Pa. State University, For. Symp., pp. 16-21.

1103. Vorob'ev, F.K., and J.P. Ch'A. 1960. Effect of simazine and 2,4-D on nitrogen metabolism of plants. Diklady Moskov. Sel'-skhorkhoz. Akad. K.A. Timirjazeva 57: 63-69.

1104. van Overbeck, J. 1962. Physiological responses of plants to herbicides. Weeds 10: 170-174.

1105. Ashton, F.M. 1963. Effect of EPTC on photosynthesis, respiration, and oxidative phosphorylation. Weeds 11: 295-297.

1106. Brian, R.C. 1964. The effects of herbicides on biophysical processes in the plant. In: The Physiology and Biochemistry of Herbicides, L.J. Audus, ed., Academic Press, New York. pp. 357-386.

1107. Ashton, F.M. 1965. Physiological, biochemical, and structural modifications of plants induced by atrazine and monuron. Proc. Southern Weed Conf. 18: 596-602.

1108. Couch, R.W., and D.E. Davis. 1966. Effect of atrazine, bromacil, and diquat on $C^{14}O_2$ fixation in corn, cotton and soybeans. Weeds 14: 251-254.

1109. Ries, S.K., H. Chmiel, D.R. Dilley, and P. Filner. 1967. The increase in nitrate reductase activity and protein content of plants treated with Simazine. Proc. Nat. Acad. Sci. U.S. 58: 526-532.

1110. Sasaki, S., and T.T. Kozlowski. 1967. Effect of herbicides on carbon dioxide uptake by pine seedlings. Can. J. Bot. 45: 961-971.

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1112. Peterson, C.A., and M. Newton. 1968. Physiological response of Douglas Fir to atrazine in sand culture and clay loam soil. Proc. 22nd Western Soc. Weed Sci. 1968: 9-10.

1113. Sasaki, S., and T.T. Kozlowski. 1968. Effects of herbicides on respiration of red pine (Pinus resinosa Ait.) seedlings. I. s-Triazine and chlorophenoxy acid herbicides. Adv. Frontiers Plant Sci. 22: 187-202.

1114. Sasaki, S., and T.T. Kozlowski. 1968. Effects of herbicides on respiration of red pine seedlings. II. Monuron, diuron, DCPA, dalapon, CDEC, CDAA, EPTC, and NPA. Bot. Gaz. 129 (4): 286-293.

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1116. Kljucnikov, L. Ju., and M.V. Bagaeva, 1969. Physiological reactions of conifers to treatment with 2,4-D in young mixed stands. Fiziol. Rast. 16 (3): 443-6.

1117. Leuhina, T.A. 1970. The physiological condition of Oak plantations after treatment with arboricides. Lesn. 2. 13 (2): 24-7.

1118. Borger, G.A., and T.T. Kozlowski. 1972. Effect of growth regulators and herbicides on normal and wound periderm ontogeny in *Fraxinus pennsylvanica* seedlings. Weed Res. 12: 190-194.

Cross references: 327, 465, 575, 590, 594, 598, 602, 604, 608, 616, 622, 623, 624, 713, 740, 1120, 1124, 1133, 1139, 1142, 1162, 1179, 1189, 1245, 1281, 1300, 1330, 1367, 1374, 1534, 1538, 1581, 1584, 1599.

B. Effects on nutrient uptake and nutrient content of plants

1119. Lynn, G.E., and K.C. Barrons. 1952. The hydrocyanic acid (HCN) content of wild cherry leaves sprayed with a brush killer containing low volatile esters of 2,4-D and 2,4,5-T. Northeastern Weed Control Conf., Proc. 6: 331-332.

The experiment was designed to test the allegation that wild cherry trees sprayed with herbicides develop increased levels of HCN and therefore become more toxic to cattle. Different species of cherry were found to vary in foliar HCN, and wilted pin cherry foliage was found to have less HCN than fresh foliage. Pin cherry sprayed with 2,4-D and 2,4,5-T was found to have lower levels of foliar HCN than untreated trees. It is concluded that herbicide spraying does not render wild cherry species more hazardous to cattle. 2 refs.

1120. Cooke, A.R. 1957. Influence of 2,4-D on the uptake of minerals from the soil. Weeds 5: 25-28.

Radioisotopes of potassium (^{42}K), chlorine (^{36}Cl), calcium (^{45}Ca) and sulphur (^{35}S) were used to study the effect of foliar applications of 2,4-D on the uptake of these elements from soil by bean plants. The herbicide treatment greatly accelerated ^{42}K uptake at 8 hours post-treatment, but by 24 hours there was a great inhibition of uptake. The same pattern was observed for ^{36}Cl and ^{45}Ca, although for calcium the inhibition was not obvious until 48 hours after herbicide application. There was very little herbicide stimulation of ^{35}S uptake and inhibition was considerable by 24 hours. The observed patterns of uptake were attributed to the effects of herbicide on plant respiration; the initial low levels of herbicide absorbed produce an increase, but this is depressed as soon as phytotoxic amounts of herbicide are taken up. 7 refs.

1121. Ries, S.K., R.P. Larsen, and A.L. Kenworthy. 1963. The apparent influence of simazine on nitrogen nutrition of peach and apple trees. Weeds 11: 270-273.

Most increases in growth and yield accompanying the use of herbicides have been ascribed to a reduction in weed competition for nutrients and water. This study examined the effects of herbicides on the growth and yield of fruit trees and examined if any increases could be related to herbicide-induced changes in nitrogen nutrition. Foliar nitrogen and shoot growth was examined in 5 year olf fruit trees around which weeds had been controlled by hoeing, a black plastic mulch, or by simazine and amitrole-T application, and with different levels of added nitrogen. The herbicide treatments resulted in higher nitrogen and more growth than the hoeing, mulching, control treatments, or nitrogen fertilizer treatments. It is concluded that the herbicides effect growth and nitrogen nutrition by affecting nitrogen metabolism in addition to reducing competition for soil moisture and nutrients. 9 refs.

1122. Gramlich, J.V. and D.E. Davis. 1967. Effect of atrazine on nitrogen metabolism of resistant species. Weeds 15 (2): 157-160.

Both corn and Johnson grass seeds were planted in sandy loam soil in the field and treated with three preemergence levels of atrazine. Similar plantings were made in loamy fine sand in growth chamber studies and five day old seedlings of the two species were grown in nutrient culture. All plants were harvested between 10 and 18 days following herbicide treatment. Plants of both species and under all treatments were smaller than untreated plants and contained higher percentages of nitrogen. However, because of the reduced size, total nitrogen per plant was reduced by the herbicide treatment. Percentage increases in nitrogen were proportional to the rate of atrazine application. Concentrations of insoluble N, 80% ethanol soluble N, and nitrate N all showed increases, while free ammonia N was unaffected. 12 refs.

1123. Conner, B.J., and D.P. White. 1968. Triazine herbicides and the nitrogen nutrition of conifers. Quartly Bulletin (Michigan Agricultural Expt. Sta.) 50 (4): 497-503.

Simazine and atrazine were applied in nutrient solution at sub-phytotoxic levels to slash and loblolly pine seedlings. Nitrogen was present in the solution as either KNO_3 or $(HN_4)_2SO_4$ (with N-serve to prevent oxidation to nitrate by Nitrosomonas). The concentration of foliar nitrogen was increased 24% by 0.8 ppm simazine with a linear relationship between nitrogen increase and simazine concentration down to 0.2 ppm simazine. This 24% increase was equivalent to tripling the amount of both nitrate and ammonium nitrogen in the nutrient solution in the absence of the herbicide. 0.4 ppm atrazine increased foliar N by 9.4%. Shoot/root ratios were significantly increased (p 0.01) by 0.8 ppm simazine as a result of a reduction in root growth. 7 refs.

1124. Ries, S.K. 1968. Spray-on protein boosters. Crops and Soils 20: 15-17.

The paper describes experiments which examined the ability of simazine to affect plant protein levels. Low levels of simazine applied to sensitive plants increases the respiration rate, increases nitrate uptake and the amount of nitrate reductose enzyme. The increased levels of nitrate are reduced to ammonia which is then incorporated into amino acids and ultimately into protein. This holds promise for increasing the efficiency of utilization of nitrogen fertilizers, thus reducing the size of applications. The nutritional merits of the increased protein content requires further study, however. No refs.

1125. Baur, J.R., R.W. Bovey, and C.R. Benedict. 1970. Effect of picloram on growth and protein levels in herbaceous plants. Agron. J. 62: 627-630.

Seed of eight species of herbaceous plants were grown in sand with added nutrients. Picloram at concentrations of 0-1000 ppb was added 14 days after planting. After a further 21 days aerial portions of the plants were dipped and weighed. Plants from each treatment were analysed for protein. The treatments resulted in reduced soluble protein concentrations in all moncot species and sunflower, but increases in cotton and cowpea at the lower concentrations. Dry weight production was stimulated in five species at lower concentrations, while significant decreases showed at the higher concentrations with the dicots being the most sensitive. 25 refs.

1126. Freyman, S. 1970. Chemical curing of pine grass with atrazine and paraquat. Can. J. Plant Sci. 50: 195-197.

Atrazine and paraquat were tested as a means to improve the nutritional quality of pinegrass in the Douglas-fir zone near Kamloops. Neither were found to have a significant effect on yields or on the silica, ADF or lignin content of pinegrass. However, by the September following April or June sprays, the protein content of all paraquat treated grass and those areas receiving the highest levels of atrazine was significantly higher than in the untreated areas. 10 refs.

1127 Ries, S.K., O. Moreno, W.F. Meggitt, C.J. Schweizer, and S.A. Ashkar. 1970. Wheat seed protein: Chemical influence on and relationship to subsequent growth and yield in Michigan and Mexico. Agron. J. 62: 746-748.

Simazine at sub-toxic levels has been shown to increase the protein content and nitrate accumulation of many crops. In this study herbicide (simazine and terbocil) at sub-toxic levels and nitrogen fertilizer (ammonium nitrate on most plots with sodium nitrate or urea on the remainder) were applied to spring wheat growing in Michigan and Mexico. Second generation studies were also carried out. The herbicide increased the protein content in all tests conducted and the yield in half of them. Nitrogen fertilizer increased both the yield and the protein content in three out of four tests. 11 refs.

1128. Erickson, L.C., C.I. Seely, and K.H. Klages. 1948. Effect of 2,4-D upon the protein content of wheat. Jour. Amer. Soc. Agron. 40: 659-660.

1129. Rhodes, A., W.G. Templeman, and M.N. Thruston. 1950. Effect of the plant growth regulator 2-methyl-4-chlorophenoxyacetic acid on mineral and nitrogen contents of plants. Ann. Bot. 14: 181-198.

1130. Stahler, L.M., and E.I. Whitehead. 1950. The effect of 2,4-D on potassium nitrate levels in leaves of sugar beets. Science 112: 749-751.

1131. Weller, L.E., R.W. Leucke, C.L. Hamner, and H.M. Sell. 1950. Changes in chemical composition of leaves and roots of red Kidney bean plants treated with 2,4-dichlorophenoxyacetic acid. Plant Physiol. 25: 289-293.

1132. Wolf, D.E., G. Vermillion, A. Wallace, and G.H. Ahlgren. 1950. Effect of 2,4-D on carbohydrate and nutrient-element content and on rapidity of kill of soybean beans growing at different nitrogen levels. Bot. Gaz. 112: 188-197.

1133. Klingman, G.C., and G.H. Ahlgren. 1951. Effects of 2,4-D on dry weight, reducing sugars, total sugars, polysaccharides, nitrogen and allyl sulfide in wild garlic. Bot. Gaz. 113: 119-134.

1134. Voigt, G.K. 1954. The effect of fungicides, herbicides, and insecticides on the accumulation of phosphorus by Pinus radiata as determined by the use of P^{32}. Agron. Jour. 46: 511-513.

1135. Cooke, A.R. 1955. Effect of CMU on the biochemical composition of several legumes. Res. Rept., North Central Weed Control Conf. 12: 181-182.

1136. Cooke, A.R. 1955. Effect of 2,4-D on the uptake and distribution of potassium by bean plants. 12th Annual Res. Rept., North Central Weed Control Conf., 1955: 181.

1137. Bruns, V.F. 1957. The response of certain crops to 2,4-dichlorophenoxyacetic acid in irrigation water. Part II. Sugar beets. Weeds 5: 250-258.

1138. Bingham, S.W., and R.P. Upchurch. 1959. Some interactions between nutrient level (N,P,K,Ca) and diuron in the growth of cotton and Italian ryegrass. Weeds 7: 167-177.

1139. Wort, D.J., and B.C. Loughman. 1961. The effect of 3-amino-1,2,4-triazole on the uptake, retention, distribution, and utilization of labelled phosphorus by young barley plants. Can. J. Botany 39: 339-351.

1140. Smith, L.H., and C.M. Harrison. 1962. Effect of 2,4-dichlorophenoxyacetic acid on seedling development and uptake and distribution of calcium and phosphorus in barley. Crop Sci. 2: 31-34.

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Cross references: 3, 51, 324, 465, 575, 594, 598, 608, 616, 622, 1088, 1097, 1106, 1108, 1109, 1160, 1171, 1184, 1189, 1256, 1352, 1402, 1494.

C. Effects on plant growth and morphology

1153. Wu, C.C., T.T. Kozlowski, R.F. Evert and S. Sasaki. 1971. Effects of direct contact of Pinus resinosa seeds and young seedlings with 2,4-D or picloram on seedling development. Can. J. Bot. 49: 1737-1741.

The effects of 2,4-D and picloram at 50 and 100 ppm on the early development of Pinus resinosa seedlings were studied by exposing seeds and the subsequent seedlings to aqueous solutions of the herbicides for between 2 and 18 days. Seeds or seedlings taken every few days were studied microscopically. Both herbicides resulted in abnormal development of the seedlings. 2,4-D treatment resulted in early cessation of root growth, proliferation and expansion of parenchyma cells, followed by disorganization and collapse of those in the upper stem and callus formation. Cotyledon development was also abnormal, and there were reduced numbers of stomata and chloroplasts in the cotyledons which were fused to the primary needles. Expansion of early formed primary needles, and the initation and expansion of additional primary needles were inhibited by 2,4-D. The effects of picloram were rather similar, although picloram was more toxic at comparable dosages. 15 refs.

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A greenhouse study in which switch grass (Panicum virgatum L.) was grown in sandy clay loam soil columns with 1-2 ppm picloram added to the surface or present in a 1 inch layer at 3 inches or 6 inches depth. Root production was found to be reduced by the surface and 3 inch treatment, resulting in reduced root/shoot ratios, while the 6 inch treatment had no effect. A further experiment with sideoats grama (Boutelona curipendula (Michx.) Torr.) showed reduced root growth resulting from surface applications of picloram, but an increase with picloram at the 6 inch depth. Root/shoot ratios were unaffected, but the rooting pattern was different from that of untreated sideoats grama. 8 refs.

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D. Effects on germination

1191. Rossman, E.C., and G.F. Sprague. 1949. Effect of 2,4-D on yields of maize in the succeeding generation after treatment. Plant Physiol. 24: 770-773.

Corn plants from four inbred lines were treated with 2,4-D as young plants, at the time of tessel and ear shoot emergence, or ten days after pollination. Hand pollination was conducted to produce all possible crosses. Yields of corn and subsequent growth of seeds were studied. The results indicated that in some cases there was a carry over of the herbicide treatment into the succeeding generations, and significant reductions in grain were obtained from some of the single crosses. 1 ref.

1192. Lee, W.O. 1966. Effect of annual applications of diuron on seed yields of perennial grasses in Oregon. U.S.D.A., Oregon Agr. Exp. Sta. Tech. Bull. 1358. 23 pp.

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E. Effects on germination

1193. Sasaki, S., and T.T. Kozlowski. 1968. Effects of herbicides on seed germination and early seedling development of Pinus resinosa. Bot. Gaz. 129: 238-246.

Three experiments were conducted to examine the acute toxicity of herbicides for seed germination and seedling development: (1) exposure to commercial formulations at 4,000 ppm; (2) exposure to active ingredients alone at 4,000 ppm; (3) exposure to commercial formulations at 100,500, 1000 and 4,000 ppm. Herbicides tested were atrazine, monuron, DCPA, NPA, CDEC, EPTC, CDAA and 2,4-D. Effects on germination varied from zero to total inhibition, the active ingredient generally acting the same as the commercial formulation. Growth of young seedlings was variously affected, the main effect being inhibition of cotyledon development. Root growth was generally more inhibited than shoot growth. It is noted that the high acute phytotoxicities of herbicides is often masked in soil cultures as the result of leaching, sorption or decomposition. 19 refs.

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1201. Kurth, I.R., and J.C. vanDorsser. 1969. Tolerance of ten tree species to propazine, dacthal and linuron pre-emergence sprays on seedbeds. New Zealand Forest Serv., Research Leaflet No. 26, 4pp.

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F. Phytotoxicity and resistance

1202. Gratkowski, H.J. 1961. Toxicity of herbicides to three northwestern conifers. USFS PNW Res. Pap. 42, 24 pp.

Reports a study of the effects on conifer regeneration of 2,4-D and 2,4,5-T applied with three different carriers in midsummer and early autumn after height growth had ended and buds were set. Responses of Douglas-fir, sugar pine and ponderosa pine regeneration of between 4 and 8 feet in height is shown pictorially. The early autumn sprays were much less damaging than the midsummer sprays. The pines were much more susceptible to damage than the Douglas-fir, and more so with 2,4-D than 2,4,5-T. Of the three formulations, a 5% diesel oil emulsion produced the greatest damage to the conifers. 9 refs.

1203. Slife, F.W., J.L. Key, S. Yamaguchi, and A.S. Crafts. 1962. Penetration, translocation and metabolism of 2,4-D and 2,4-5-T in wild and cultivated cucumber plants. Weeds <u>10</u>: 29-35.

The difference in toxicity of 2,4-D and 2,4-5-T to many plants has been thought to be a function of differences in absorption and translocation, metabolic detoxification, or instrinsic differences in sensitivity. Autoradiography and ^{14}C were used to study absorption, translocation, and metabolic degradation of leaf and root-labelled wild and cultivated cucumber plants. In wild cucumber, 2,4-D penetrated rapidly and moved throughout the plant within 24 hours when applied to leaves, while root applications remained in the roots. 2,4,5-T showed exactly the reverse. Cultivated cucumber showed less difference in response to the two herbicides. Considerably more 2,4-D is absorbed than 2,4,5-T in both species, but 75% of the 2,4-D is converted to other compounds within 24 hours. Only traces of such secondary compounds were formed from 2,4,5-T after 8 days. Decarboxylation, measured by release of ^{14}C was 10 times greater in 2,4-D labelled than in 2,4,5-T labelled plants. The greater phytotoxicity of 2,4,5-T to these species as compared with 2,4-D appears to be related to the relative ability of plants to metabolically detoxify these two herbicides. 17 refs.

1204. Muzik, T.J., and W.G. Mauldin. 1964. Influence of the environment on the response of plants to herbicides. Weeds <u>12</u>: 142-145.

The phytotoxicity of herbicides varies according to environmental conditions and the physiological condition of the plant. Some plants are sensitive to 2,4-D in the vegetative stage but quite resistant during the flowering stage. Absorption and translocation of leaves and roots is reduced at low temperatures. This study examined the effect of temperature on growth and susceptibility to 2,4-D at different stages of growth and its effect on translocation of 2,4-D. Attempts were made to modify the effects of temperature by the addition of certain metabolites. Peas, tomatoes which are temperature sensitive, a temperature resistant winter wheat, and a temperature resistant weed, fiddleneck, were studied. Sensitivity to 2,4-D was greater at 26°C than at 10°C or 5°C at all stages of growth. The response of wheat to triazine herbicides was influenced by local environmental conditions at the time spraying. Application of thiamin increased the sensitivity of fiddleneck to 2,4-D at low temperatures. Other metabolites produced similar but smaller increases. The lack of such metabolites at low temperature may confer resistance to the herbicide. 9 refs.

1205. Negi, N.S., H.H. Funderburk, Jr., and D.E. Davis. 1964. Metabolism of atrazine by susceptible and resistant plants. Weeds 12: 53-57.

Concentrations of undegraded ^{14}C-labeled atrazine were measured in a variety of agricultural plants varying in susceptibility to this herbicide. A metabolic degradation product, hydroxyatrazine, was also investigated. Levels of undegraded atrazine were roughly correlated with susceptibility, but there was no clear correlation between atrazine uptake and susceptibility. All plants converted some atrazine to hydroxyatrazine, but resistant species converted at least twice as much as susceptible varieties. 16 refs.

1206. Bickford, M., and R.K. Hermann. 1967. Herbicide aids survival of Douglas fir seedlings planted on dry sites in Oregon; root wrapping has little effect. Tree Planters' Notes 18 (4): 1-4.

Describes experiments on the effects of the wrapping (containerising) of roots and atrazine applications on the survival of Douglas-fir seedlings planted in a grassy community on south facing slope with a heavy clay soil. Root wrapping did not have any effect on survival, whereas herbicide application had a favourable result. This is attributed to a reduction in competition for water. However, the root wrapping may protect roots from a possible adverse effect of high concentrations of atrazine in the soil. 4 refs.

1207. Kozlowski, T.T., S. Sasaki, and J.H. Torrie. 1967. Effects of temperature on phytotoxicity of monuron, picloram, CDEC, EPTC, CDAA, and sesone to young pine seedlings. Silva Fennica 3(2): 13-28.

A growth chamber study of the effect of temperature over the range 10-30°C on the phytotoxicity of six herbicides incorporated into the soil for *Pinus resinosa* seedlings. High toxicity of picloram and monuron was reflected in reduced seedling survival and dry weight increment, with phytotoxicity being greatly enhanced at high temperatures (25° and 30°C). Reliable information on the other herbicides was not obtained due to large losses of the herbicides before the seeds were planted. 20 refs.

1208. Norris, L.A. 1967. The physiological and biochemical bases of selective herbicide action. In: Herbicide and Vegetation Management, Symp. (Oregon State University). pp. 56-66.

Three types of selectivity are identified: different species responding differently to one herbicide, one species responding differently to different herbicides, and one species responding differently to one herbicide when growing in different areas. Selectivity is controlled by uptake, translocation, and detoxification which all influence the arrival of the herbicide at the site of action in an active form. Uptake controls the amount of herbicide available for translocation, and is in turn influenced by spray retention by the foliage. Translocation increases as absorption increases only to the point at which the toxicity of the herbicide inhibits the transport system. The mobility of different herbicides within plants varies greatly and this determines how much herbicide reaches the site of action. Many herbicides are subject to metabolic alteration by the plant, and in several plants this is the major determinant of selectivity. Many examples are given of these different parameters of selectivity. As a working example, the greater effectiveness of 2,4,5-T on bigleaf maple as compared to 2,4-D is examined in terms of uptake, translocation, detoxification, and temporal stability. A simple formula expressing the ultimate effectiveness of a herbicide is presented. This permits a comparison between different herbicides in a given type of application. 18 refs.

1209. . Weber, J.B., P.W. Perry, and K. Ibaraki. 1968. Effect of pH on the phytotoxicity of prometryne applied to synthetic soil media. Weed Sci. 16: 134-136.

Phytotoxicity of prometryne to wheat seedlings grown in sand with nutrient solution was significantly reduced by the addition of montmorillonite clay and soil with a high organic matter content. The reduction in phytotoxicity was greater when the pH was 4.5 than when it was 6.5. At the lower pH more of the prometryne was present in the protonated form which becomes bound to the soil additives. Adsorption mechanisms are postulated and discussed. 13 refs.

1210. Wheeler, H.L., and R.H. Hamilton. 1968. The leaf concentrations of atrazine in cereal crops as related to tolerance. Weed Sci. 16 (1): 7-10.

Wheat and sorghum, both very resistant to atrazine, were exposed to atrazine in solution culture. After prolonged treatment (20-25 days) with high concentrations, these resistant species accumulated leaf concentrations of unaltered atrazine comparable to those found in sensitive species at the point of acute toxicity. Leaf concentrations could be increased by raising the atrazine application rate or lowering the temperature at which the plants were grown. Acute toxicity symptoms in sensitive plants were closely related to loss of chlorophyll. 12 refs.

1211. Upchurch, R.P., H.D. Coble, and J.A. Keaton. 1969. Rainfall effects following herbicidal treatment of woody plants. Weed Science, 17 (1): 94-8.

Turkey oak resprouts on an area cleared for conifer plantations were sprayed with one of two formulations of 2,4,5-T or a mixture of picloram and 2,4-D. Each herbicide was applied at three different levels and simulated rainfalls of ½ or one inch were applied 5, 15, 60 or 120 minutes following herbicide application. The treated areas were evaluated the following year. Neither the effects of the ester nor those of the amine formulation of 2,4,5-T were reduced by any of the rainfall treatments. The phytotoxic effects of the 2,4-D/picloram mixture were markedly reduced by both precipitation intensities and at all of the intervals after herbicide application. Since turkey oak is relatively resistant to 2,4-D, this is interpreted as representing the effect of rainfall on picloram. The degree to which picloram effectiveness is diminished will depend upon the amount of rainfall, the interval between applications and rain, and the rate at which the picloram is applied. 14 refs.

1212. Stahler, L.M. 1945. Tolerance of crop plants to spray solutions of 2,4-D and other selective herbicides. North Central Weed Control Conf., Research Report 2: 36-41.

1213. Smith, H.H. 1946. Quantitative aspects of aqueous spray applications of 2,4-D acid for herbicidal purposes. Bot. Gaz. 107: 544-551.

1214. Weaver, R.J., C.E. Minarik, and F.T. Boyd. 1946. Influence of rainfall on the effectiveness of 2,4-dichlorophenoxyacetic acid sprayed for herbicidal purposes. Bot. Gaz. 107: 540-544.

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1216. Kraus, E.J., and J.W. Mitchell. 1947. Growth-regulating substances as herbicides. Bot. Gaz. 108: 303.

1217. Marth, P.C., and J.W. Mitchell. 1947. Selective herbicidal effects of 2,4-D applied to turf in dry mixture of fertilizers. Bot. Gaz. 108: 414-420.

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1219. Anderson, W.P., P.J. Linder, and J.W. Mitchell. 1952. Evaporation of some plant growth regulators and its possible effect on their activity. Science 116: 502-503.

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1223. Buchholtz, K.P. 1954. Some factors affecting the tolerance of peas to MCP and other growth regulating herbicides. Weeds 3: 331-341.

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1226. Fisher, C.E., C.H. Meadors, and R. Behrens. 1956. Some factors that influence the effectiveness of 2,4,5-T acid in killing mesquite. Weeds 4 (2): 139-147.

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1234. Rummukainen, U. 1962. Experiments with simazin. Communicationes Instituti Forestalis Fenniae 55.20, 13 pp.

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1238. Pallas, J.E., Jr. 1963. Absorption and translocation of the triethylamine salt of 2,4-D and 2,4,5-T in four woody species. Forest Sci. 9: 485-491.

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1241. Hacskaylo, J., J.K. Walker, Jr., and E.G. Pires. 1964. Response of cotton seedlings to combinations of preemergence herbicides and systemic insecticides. Weeds 12: 288-291.

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G. Entry into plants

1270. Orgell, W.H., and R.L. Weintraub. 1957. Influence of some ions on foliar absorption of 2,4-D Bot. Gaz. 119 (2): 88-93.

The influence of several cations and anions on penetration of 2,4-D into leaves of 7 day old bean plants was studied by the measurement of growth responses. Short term effects were assessed by measuring epicotyl curvature after 2 hours, while longer term effects were based on measurements 3-6 days post-application. In the absence of other cations, the rate of absorption was dependent on the hydrogen ion content. Under more acid conditions, the 2,4-D is less dissociated and it is thought that 2,4-D penetrates the plasma membrane most rapidly in the undissociated form. Under neutral or alkaline conditions, absorption was markedly influenced by certain cations. Ammonium and ethanolammonium ions, supplied as salts of 2,4-D or as buffer cations induced responses in alkaline conditions equivalent to those observed in acid conditions. Potassium and sodium ions did not evoke this response, however. The cation effect was somewhat influenced by certain anions and surfactants. 10 refs.

1271. Currier, H.B., and C.D. Dybing. 1959. Foliar penetration of herbicides-review and present status. Weeds 7: 195-213.

Pathways of initial penetration into leaves are reviewed, including the effects of cuticle, wax, epidermal differences, stomata, hydathodes, lenticels and hairs. Movement from the cuticle to other internal tissues is discussed and evidence for alternative pathways is reviewed. Factors affecting penetration and movement are discussed including cuticle, stomata, water balance, leaf morphology, leaf age, leaf injury, metabolic condition, environmental factors, spray formulation, and method of application. 182 refs.

1272. Davis, D.E., H.H. Funderburk, Jr., and N.G. Sansing. 1959. The absorption and translocation of C^{14}-labeled simazine by corn, cotton and cucumber. Weeds 7: 300-309.

There was no obvious correlation between susceptibility and the amount of simazine absorbed by the plants, if the measure of absorption employed is valid. Root uptake was rapid, but almost no uptake occurred via intact leaves. Resistance appeared to be correlated with degree of degradation of simazine. 7 refs.

1273. Pallas, J.E., Jr. and G.G. Williams. 1962. Foliar absorption and translocation of P^{32} and 2,4-dichlorophenoxyacetic acid as affected by soil-moisture tension. Bot. Gaz. 123: 175-180.

This study examined the effects of soil-moisture stress at low tension on the foliar absorption and translocation of ^{14}C-labeled 2,4-D and ^{32}P in bean plants. The herbicide was applied to the leaves, and uptake and translocation determined by counting in a gas-flow counter and by autoradiography. Over a soil moisture range of 7.8%-13.8% no effect was found on the absorption of 2,4-D, but about twice as much 2,4-D was translocated at 1/3 atmosphere as compared with 4 atmosphere tension. More ^{32}P was absorbed and 8 times as much was translocated below 1/3 atmosphere as compared with 3 atmosphere tension. 24 refs.

1274. Foy, C.L. 1964. Review of herbicide penetration through plant surfaces. J. Agr. Food Chem. 12: 473-476.

The complexity and interaction of factors governing the effectiveness of foliage-applied herbicides is becoming increasingly apparent. Factors influencing foliar penetration are reviewed and there is a discussion of polar vs apolar routes across the cuticle. As an aid to understanding penetration, the properties of such cuticular components as cutin, waxes, pectins, and cellulose are reviewed. Postulated absorption pathways are discussed. Surfactant action and the accumulation of herbicide residues on the leaf surface are reviewed and future research needs identified. 29 refs.

1275. Hacskaylo, J. (Ed.) 1964. Absorption and translocation of organic substances by plants. 7th Ann. Symp., Amer. Soc. Plant Physiologists, S. Sect.

This is a collection of four review papers: 1) Mechanisms of root absorption of organic molecules (C.L. Foy and S. Yamaguchi, 76 refs.) 2) The effect of free space enzymes on uptake of organic molecules (J.A. Sacher, 50 refs). 3) Leaf structure as related to penetration of organic substances (H.M. Hull, 222 refs). 4) The entry of solutes into leaves by means of ectodesmata (W. Frauke, 29 refs.)

1276. Bovey, R.W., F.S. Davis, and M.G. Merkle. 1967. Distribution of picloram in huisache after foliar and soil application. Weeds 15: 245-249.

Potassium salt of picloram was applied to soil, foliage, or soil plus foliage of manually defoliated or non-defoliated Acacia farnesiana (L.) Willd. grown in the greenhouse. Soil applications of 1/8 lb/acre were more effective than foliar applications; both were lethal at 1/2 lb/acre on non-defoliated plants. Defoliated trees were able to withstand this rate, while manual defoliation within 24 hours of foliar application prevented mortality of trees which had foliage at the time of application. Picloram content of leaves, stem and roots was determined by gas chromatography for 30 days post-treatment. Most of the picloram applied to the foliage remained in or on the leaves over this period; none was found in the leaves 30 days after soil treatment. Concentrations in roots and foliage from soil and foliar treatments, respectively, were similar. Absorption and movement studies indicated that an exposure time of 24 hours was required to move lethal amounts of picloram into roots and leaves. 5 refs.

1277. Hull, H.M. 1967. Uptake and movement of herbicides in plants. In: Herbicides and Vegetation Management. Symp., Oregon State Univ., pp. 49-55.

There is a brief review of literature pertaining to factors influencing foliar uptake. The importance of applying herbicides to coincide with periods of maximum within-plant redistribution of materials is stressed since these conditions favour uptake. However, maximum toxicity is apparently related to minimum movement throughout the plant, presumably because the resultant dilution reduces toxicity. The precise molecular formulation is important in uptake and translocation. Poor root uptake sometimes is offset by little translocation from the roots with resultant high toxicity. There is a general discussion of the toxicity of 2,4-D, 2,4,5-T, and picloram and some factors affecting it including the role of carriers, surfactants, and synergists. The importance of droplet size in effecting drift, effectiveness and selectivity is discussed. 28 refs.

1278. Brady, H.A. 1970. High temperature boosts 2,4,5-T activity in woody plants. Proc. 23rd. Meeting Southern Weed Sci. Soc. 23: 234-236.

In a growth chamber study, one year old seedlings of seven woody species (one conifer and six broadleaved species) received foliar applications of ^{14}C-labelled isooctyl ester of 2,4,5-T. Plants were harvested 96 hours later, and uptake and translocation studied by liquid scintillation. Experiments were conducted at 95°, 75° and 55°F. All species absorbed more of the herbicide at 95° than 55°F. For 2,4,5-T susceptible species there was a positive relationship between uptake and temperature at all three temperatures. For the resistant and moderately resistant species the data are less clear. In four of the species, the greatest downwards translocation to the roots occurred at the higher temperature: in the other three (including loblolly pine) greatest translocation to the roots occurred at the lower temperature. 2 refs.

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1280. Rice, E.L. 1948. Absorption and translocation of ammonium 2,4-dichlorophenoxyacetate by bean plants. Bot. Gaz. 109: 301-314.

1281. Crafts, A.S. 1950. The physiology of weed control. 12th Ann. West. Weed Conf., Proc. pp. 61-69.

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1313. Davis, F.S., R.W. Bovey, and M.G. Merkle. 1968. The role of light, concentration, and species in foliar uptake of herbicides in woody plants. Forest Sci. 14: 164-169.

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H. Translocation in plants

1323. Hay, J.R. 1956. Translocation of herbicides in marabu. II. Translocation of 2,4-dichlorophenoxyacetic acid following foliage application. Weeds 4: 349-356.

Marabu is rarely killed by single aerial applications of 2,4-D; defoliation is the main effect. Transport of foliarly-applied 2,4-D to woody material was investigated using a bioassay. Less than 1% of the 2,4-D applied moved from foliage to woody parts and such movement ceased after 24 hours. Phytotoxic amounts did not move through living tissues, presumably because of interference with transport mechanisms. Sufficient 2,4-D was transported, however, to affect bud formation. 12 refs.

1324. Fang, S.C. 1958. Absorption, translocation and metabolism of 2,4-D-1-C^{14} in pea and tomato plants. Weeds 6: 179-186.

Pea plants were found to absorb 2,4-D applied to leaves for 24 hours, while in tomato plants movement from leaves to the rest of the plant continued throughout the 7-day experimental period. In contrast to the situation for bean plants, the absorbed material accumulated in the lower stem and roots of the pea and tomato plants. 7 refs.

1325. Leonard, O.A., D.E. Bayer, and R.K. Glenn. 1966. Translocation of herbicides and assimilates in red maple and while ash. Bot. Gaz. 127: 193-201.

Amitrole and 2,4,5-T (as three different formulations) were sprayed on the leaves or applied to cuts in the bark of red maple and white ash seedlings (3-4 years old). Amitrole was absorbed and transported throughout the plant with either method of application. 2,4,5-T was neither exported from leaves nor translocated in the stem. Both herbicides caused a significant transport of ^{14}C assimilates from a labelled leaf into other leaves. Application of herbicide to a leaf restricted translocation from that leaf to the roots, but treatment of adjacent leaves had much less effect. Movement of assimilates and herbicides were studied by means of autoradiography and ^{14}C labelling. 13 refs.

1326. Crafts, A.S. 1967. Bidirectional movement of labeled tracers in soybean seedlings. Hilgardia 37 (16): 625-638.

The study used ^{14}C-labeled herbicides to show the following results: 2,4-D translocation is largely restricted to the phloem; monuron movement occurs in xylem and cell walls as the result of apoplastic processes; amino triazole moves in phloem, xylem, and cell walls; maleic hydrazide may leak from phloem to xylem and thus circulate in the plants; 16 refs.

1327. Yamaguchi, S., and A.S. Islam. 1967. Translocation of eight C^{14}-labeled amino acids and three herbicides in two varieties of barley. Hilgardia 38 (5): 207-229.

2,4-D showed very little phloem mobility and zero xylem mobility. Amitrole was less than half as mobile as the amino acids tested. Monuron was distributed by the apoplast system and had a high mobility in the xylem. Translocation of 2,4-D from treated leaves lasted less than 11 hours, while amitrole continued to be redistributed over the 14-day life of the experiment. 4 refs.

1328. Brady, H.A. 1969. Light indensity and the absorption and translocation of 2,4,5-T by woody plants. Weed Sci. 17 (3): 320-322.

The isooctyl ester of 2,4,5-T was applied to the tops of water oak, post oak, longleaf pine, and American holly seedlings preconditioned for 2 weeks at one of 4 light intensities. Distribution of 2,4,5-T in the plants was studied after harvesting by gas chromatography. Absorption varied more than 20% between species. There was a linear increase for the evergreen species while the deciduous species showed a peak at an intermediate light intensity. Translocation was unaffected by varying light intensity in pine and holly, while the 2 deciduous species showed both increasing and decreasing responses. 2,4,5-T exposed to high light intensity showed a rapid curvilinear disappearance with 60% being lost in the first 8 hours and 20% being lost after 96 hours. 9 refs.

1329. Reid, C.P.P., and W. Hurtt. 1969. Translocation and distribution of picloram in bean plants associated with nastic movements. Plant. Physiol. 44 (10): 1393-1396.

Root systems of young bean plants were immersed in nutrient solution containing ^{14}C-labeled picloram for periods of 3-11 hours. Liquid scintillation and autoradiographic techniques were used to study within-plant distribution of the labeled material. Bending of upper stem and leaves accompanied accumulations of very small amounts of picloram. Greatest accumulation was associated with the terminal buds. The results contradicted earlier reports that the translocation characteristics of 2,4-D and picloram are similar. Picloram was found to move rapidly out of the roots to areas of high metabolic activity whereas other studies have shown little translocation of 2,4-D away from roots. It is concluded that very low concentrations of picloram can cause morphological aberrations in plants, and that xylem transport may not necessarily be the only pathway of picloram movement. 13 refs.

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1336. Minshall, W.H. 1954. Translocation path and place of action of 3-(4-chlorophenyl)-1,1-dimethylurea in bean and tomato. Can. J. Bot. 32: 795-798.

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1347. Leonard, O.A., and R.J. Hull. 1965. Translocation relationships in and between mistletoes and their hosts. Hilgardia 37 (4): 115-153.

1348. Badiei, A.A., E. Basler, and P.W. Santelmann. 1966. Aspects of movement of 2,4,5-T in blackjack oak. Weeds 14 (4): 302-305.

1349. Crafts, A.S. 1966. Relation between food and herbicide transport. In: Isotopes in Weed Research. International Atomic Energy Agency, Vienna, pp. 3-7.

1350. Baur, J.R., and R.W. Bovey. 1969. Distribution of root-absorbed picloram. Weed Sci. 17: 524-528.

1351. Duble, R.L., E.C. Holt, and G.G. McBee. 1969. Translocation and breakdown of disodium methane arsonate (DSMA) in coastal bermudagrass. J. Agr. Food Chem. 17: 1247-1250.

1352. Sckerl, M.M., and R.E. Frans. 1969. Translocation and metabolism of MAA-^{14}C in Johnsongrass and cotton. Weed Sci. 17: 421-427.

Cross references: 8, 173, 246, 286, 445, 467, 531, 567, 587, 588, 594, 597, 598, 608, 616, 618, 622, 634, 648, 666, 677, 713, 911, 936, 1102, 1203, 1204, 1208, 1233, 1236, 1238, 1266, 1271, 1275, 1277, 1278, 1280, 1281, 1282, 1283, 1284, 1286, 1287, 1288, 1290, 1291, 1294, 1295, 1296, 1297, 1299, 1273, 1300, 1301, 1306, 1307, 1309, 1310, 1312, 1315, 1316, 1318, 1320, 1321, 1376, 1378, 1534, 1542.

I. Effects on plant pathogens

1353. Chappell, W.E., and L.I. Miller. 1956. The effects of certain herbicides on plant pathogens. Plant Disease Reporter 40: 52-56.

Weed control in peanut fields has resulted in improved growth and vigour of the peanut plants. Laboratory studies showed that certain herbicides were controlling several parasitic fungi and a species of nematode. Subsequent field studies on the effects of the herbicides on the development of various diseases and infections on peanuts did not definitely establish fungicidal or nematocidal action by the herbicides, but suggested that disease development may be influenced by herbicide use. No refs.

1354. Quick, C.R. 1964. Experimental herbicidal control of dwarf mistletoe on some California conifers. USFS Res. Note PSW-47, 9 pp.

A report of exploratory tests involving 50 herbicide formulations applied in 246 tests on 2516 trees of 5 species against dwarf mistletoe. As isooctyl ester of 2,4,5-Trichlorophenoxy butyric acid was the most promising combining minimum tree damage with maximum mistletoe control. No refs.

1355. Chansler, J.F., and D.A. Pierce. 1966. Bark beetle mortality in trees injected with cacodylic acid (herbicide). J. Econ. Ent. 59 (6): 1357-1359.

Ansar 160 and Silvisar 510, both containing cacodylic acid, were injected into Ponderosa pine, Douglas-fir and Engelmann spruce. Results showed fewer bark beetle attacks on treated than on untreated Ponderosa pine. Nearly all parent adults died before completing egg galleries in treated trees, and percentage egg hatch was reduced. The greatest brood mortality in treated trees occurred during the first larval instar with reductions as great as 99%. It is claimed that herbicides have great potential for bark beetle control because of low cost, operator safety, ease of application, less environmental contamination, and lower hazard to non-target insects than insecticide alternatives. It is not known if the herbicide acts directly as an insecticide or indirectly through the host tree. 4 refs.

1356. Buffam, P.E. 1971. Spruce beetle suppression in trap trees treated with cacodylic acid. J. Econ. Entomol. 64 (4): 958-960.

Different application rates and dates of cacodylic acid were studied to discover the combination that would make treated spruce trees as attractive to the spruce beetle as untreated trees and yet be lethal to the beetles. Half-strength Silvisar-510 applied in mid-June with the trees felled two weeks later provided this combination. Woodpecker activity was noted to be much less on the treated trees in spite of their completement of insect attacks. 7 refs.

1357. Buffam, P.E., and H.W. Flake, Jr. 1971. Roundheaded Pine Beetle mortality in cacodylic acid-treated trees. J. Econ. Entomol. 64 (4): 969-970.

Describes an experiment to control an outbreak of roundheaded pine beetle by frilling recently attacked green trees and injecting the frill with Silvisar 510. This was found to give 100% mortality of parent adults. Hand frilling with a hatchet was more successful than with a power saw. 4 refs.

1358. Frye, R.H., and N.D. Wygant. 1971. Spruce beetle mortality in cacodylic acid-treated Engelmann Spruce trap trees. J. Econ. Entomol. 64 (4): 911-916.

Cacodylic acid (as Silvisar 510) was applied to frill girdled Englemann spruce which were felled 9-14 days after post treatment and tested as trap trees. The treated trees were fatal to Dendroctonus rufipennis (Kirby) and several other phloem-feeding bark beetles, but were highly attractive to ambrosia beetles. The effect on bark beetles was thought to be indirect (by inducing anaerobic fermentation) rather than by direct chemical action on the insects as the development of the ambrosia beetles was not affected. Water content of the trees was not significantly affected by the treatment, but the development of blue stain fungi was inhibited. 9 refs.

1359. Newton, M., and H.A. Holt. 1971. Scolytid and Buprestid mortality in ponderosa pines injected with organic arsenicals. J. Econ. Entomol. 64 (4): 952-958.

Sixty year old Ponderosa pines were injected with organic arsenical herbicides in a simulated precommercial chemical thinning. Materials used were cacodylic acid, MSMA, or a mixture of the two. All treatments resulted in lower attack levels than in felled, untreated trees; bark beetles were much more affected than ambrosia beetles or flat-headed borers. Season of treatment and the formulation applied both affected insect attack, probably because of the relationship of these parameters to phytotoxicity. The reduction in insect activity was reflected in reduced blue stain. Endometatoxic reactions involving reduction of the organic arsenicals to insecticidal arsines is advanced as an explanation for the insect response in addition to the conventional theory of herbicide-induced deterioration of insect habitat. 9 refs.

1360. Dowler, C.C., P.F. Sand, and E.L. Robinson. 1963. The effect of soil type on preplanting soil-incorporated herbicides for witchweed control. Weeds 11: 276-279.

1361. Webster, J.M., and D. Lowe. 1966. The effect of the synthetic plant-growth substance, 2,4-dichlorophenoxyacetic acid, on the host-parasite relationships of some plant-parasitic nematodes in monoxenic callus culture. Parasitology 56: 313-322.

1362. McGhehey, J.H., and W.P. Nagel. 1967. Bark beetle mortality in precommercial herbicide thinnings of western hemlock. J. Econ. Entomol. 60: 1572-1574.

1363. Wilkinson, V. 1969. Ecological effects of diquat. Nature 224: 618-619.

1364. Chansler, J.F., D.B. Cahill, and R.E. Stevens. 1970. Cacodylic acid field tested for control of Mountain Pine Beetles in Ponderosa Pine. Rocky Mt. For. Range Exp. Sta., Research Note RM-161. 3 pp.

1365. Driver, C.H., R.E. Wood., *et al*. 1970. Effect of thinning by herbicides on occurrence of *Fomes annosus* in young-growth Western Hemlock. Plant Dis. Reptr. 54 (4): 330-1.

1366. McDonald, T.J. 1970. Experiments in chemical control of brigalow (*Acacia harpophylla*) suckers in sheep country. Queensland J. Agric. Anim. Sci. 27: 1-15.

1367. Stelzer, M.J. 1970. Mortality of *Ips lecontei* attracted to Ponderosa pine trees killed with cacodylic acid. J. Econ. Ent. 63 (3): 956-959.

1368. Stott, K.G., 1970. Willows: relation of weeding to Willow rust. Rep. Agric. Hort. Res. Sta. Bristol Univ. 1969: 139.

1369. Buffam, P.E., and F.M. Yasinski. 1971. Spruce beetle hazard reduction with cacodylic acid. J. Econ. Entomol. 64 (3): 751-752.

Cross references: 6, 25, 222, 465, 995, 1001, 1347, 1381

J. Persistence on or in plants

1370. Reid, C.P.P., and W. Hurtt. 1970. Root exudation of herbicides by woody plants: allelopathic implications. Nature, Lond. 225 (5229): 291.

Experiments showed that picloram and 2,4,5-T are exuded from the roots of ash and maple in significant quantities following foliar application. Combined radioassay and chromatography of ^{14}C-labelled materials showed that the root exudates were the unaltered original herbicide molecules. This may be a significant ecological aspect of herbicide application. 12 refs.

1371. Scifres, C.J., R.R. Hahn, and M.G. Merkle. 1971. Dissipation of picloram from vegetation of semiarid rangelands. Weed Sci. 19 (4): 329-332.

Levels of picloram on range grasses in Texas just after spraying were about 25 ppm. This declined to 1 ppm in the grass tissues 30-60 days post-treatment; although in one place picloram levels increased in grasses from 32-60 days. This was attributed to root-uptake. Picloram residues in herbaceous, broad-leaved species, on the other hand, was reduced to 7% of the original level 30 days after the application. Disappearance of picloram from the grasses was not affected by sprinkler-irrigation. Average rates of loss of picloram were 2.5-3%, although dissipation was non-linear with peak losses soon after application. 11 refs.

1372. Ennis, W.B., Jr., R.E. Williamson, and K.P. Dorschner. 1952. Studies on spray retention by leaves of different plants. Weeds 1:274-286.

1373. Gard, L.N., C.E. Ferguson, Jr., and J.L. Reynolds. 1959. Effect of higher application rates on crop residues of isopropyl N-phanyl-carbamate and isopropyl N-(3-chlorophenyl) carbamate. J. Agr. Food Chem. 7: 335-338.

1374. Foy, C.L. 1961. Accumulation of 5-triazine herbicides in the lysigenous glands of cotton and its physiological significance. Abstracts, WSA. 1961: 41.

1375. Erickson, L.C., B.L. Brannaman, and C.W. Coggins, Jr. 1963. Residues in stored lemons treated with various formulations of 2,4-D. J. Agr. Food Chem. 11: 437-440.

1376. Colby, S.R., G.F. Warren, and R.S. Baker. 1964. Fate of Amiben in tomato plants. J. Agr. Food Chem. 12: 320-321.

1377. Katterman, F.R.H., and W.C. Hall. 1964. P^{32}-and S^{35}Olabeled S,S,S-tributyl-phosphorotrithioate defoliant residue in cottonseed. J. Agr. Food Chem. 12: 187-188.

1378. Calderbank, A., and P. Slade. 1966. The fate of paraquat in plants. Outlook Agric. 5 (2): 55-59.

1379. Morton, H.L., E.D. Robison, and R.E. Meyer. 1967. Persistence of 2,4-D, 2,4,5-T and dicamba in range forage grasses. Weeds 15 (3): 268-271.

1380. Getzendaner, M.E., J.L. Herman, and B. van Giessen. 1969. Residues of 4-amino-3,5,6-trichloropicolinic acid in grass from applications of Tordon herbicides. J. Agr. Food Chem. 17: 1251-1256.

1381. Neely, D. 1970. Persistence of foliar protective fungicides. Phytopathology 60 (11): 1583-1586.

Cross references: 608, 622, 642, 708, 897, 952, 1166, 1167, 1213, 1244, 1256, 1297, 1301, 1344, 1352, 1414, 1531, 1540.

VI. EFFECTS ON NON-SOIL ANIMALS

A. Effects on birds

1382. Bergstrand, J. and W.D. Klimstra. 1962. Toxicity of "Dybar" to bobwhite quail. J. Wildl. Mgmt. 26: 325-27.

Eight-month-old bobwhite quail were debeaked and fed pellets of fenuron (Dybar) at several different dosages over a 10 day period. Behaviour and alertness of the birds was checked periodically and body weight was monitored. No ill effects were noted, and body weight increase was greater in birds fed the herbicide pellets than in the control birds. Internal organs were analysed for fenuron residues. Only at the highest rate of feeding were any found and these were located in the kidneys. Subsequent field studies in areas where dybar was broadcast on spoilbanks failed to note any immediate effects on wildlife. No refs.

1383. Andersson, A., A. Kivimae, and C. Wadne. 1962. The toxicity of some herbicides to chicks. Kgl. Lantbrukshogskol. och Statens Lantbruksforsok, Statens Hasdjursforsok, Sartryck och Forhandsmedd, No. 155, 18 pp.

1384. Martin, N.S. 1965. Effects of chemical control of sagebrush on the occurrence of sage grouse in southwestern Montana. Unpubl. Master's Thesis, Montana State College, Bozeman. 38 pp.

1385. Fletcher, K. 1967. Production and viability of eggs from hens treated with paraquat. Nature 215: 1407-1408.

Cross references: 358, 376, 1356, 1369, 1395, 1399, 1401, 1402, 1408, 1420, 1422, 1426, 1427, 1432, 1444

B. Effects on mammals

1386. Fertig, S.N. 1952. Livestock poisoning from herbicide treated vegetation. Proc. 6th Ann. Northeast Weed Control Conf. 6: 13-19.

There is a brief review of cases of livestock deaths following herbicide spraying of pastures or adjacent areas with 2,4-D or 2,4,5-T. Results are reported of experiments to quantify nitrate increases in several weed species treated with 2,4-D or MCP. Increases were observed in all four species examined with peak nitrate accumulations occurring 2 to 3 days post treatment. No refs.

1387. Radeleff, R.D. 1958. The toxicity of insecticides and herbicides to livestock. Adv. in Vet. Sci. 4: 265-276.

A review which concludes that in general the high dosages of herbicides required to produce poisoning reduces the hazard of their use. Examples are given of the pathological effects of various herbicides on various animals. 13 refs.

1388. Buck, W.B., W. Binns, L. James, and M.C. Williams. 1961 Results of feeding herbicide-treated plants to calves and sheep. J. Am. Vet. Med. Assoc. 138 (6): 320-323.

Application of 2,4-D or 2,4,5-T to pastures is not thought to result in herbicide poisoning of livestock or poultry. They are known to affect nitrate and hydrocyanic acid metabolism of some plants, however, and nitrate poisoning of cattle by 2,4-D-treated sugar beets has been known to occur. In this study, Canadian thistle was sprayed with an ester of 2,4-D, tall larkspur with silvex (ester of 2,4,5-T), and sneezeweed with either silvex or 2,4-D. Plants were harvested at various intervals following application, dried, ground, and fed to calves and sheep via rumen fistulas. A considerable number of tests were conducted, but no major differences were observed in the effects of these plants on the animals. Some differences were observed in blood urea nitrogen, serum albumin, gamma globulin, and certain other physiological parameters of sheep fed sneezeweed sprayed with the herbicides. 13 refs.

1389. Palmer, J.S., and R.D. Radeleff, 1964. The toxicologic effects of certain fungicides and herbicides on sheep and cattle. Annals, N.Y. Acad. Sci. 111 (2): 729-736.

A summary of three years of toxicological research on insecticides, organic fungicides and herbicides in sheep and cattle. Daily doses of up to 500 mg/kg body weight were administered for up to 481 days, and the effects of various doses continued for various periods are described. The studies did not alter the generally accepted concept of the hazards presented by the herbicides studied (2,4-D, 2,4,5-T, 2 benzoic acid herbicides, 3 triazine herbicides, and 4 miscellaneous herbicides). When used as recommended, these compounds posed very little hazard to sheep and cattle. Two herbicides, a triazine and one called Bandane resulted in adenalopathy and brain haemorrhaging, respectively, and should be investigated further. 10 refs.

1390. Bohmont, B.L. 1967. Toxicity of herbicides to livestock, fish, honey bees and wildlife. Western Weed Control Conf., Proc. 21: 25-27.

A brief review of the toxicity of herbicides to cattle concludes that high levels are required to produce toxicity problems. The little wildlife data that exist are not indicative of problems. Honey bees seem to be relatively unaffected. Fish, on the other hand, are affected and some herbicides are highly toxic to them. Some fish LC_{50} (at 48 hours) data are presented. In summary, it is pointed out that for each animal group discussed there are some herbicides which are toxic, but that for many of the groups most herbicides have a low toxicity. 12 refs.

1391. Warren, L.E. 1967. Residues of herbicides and impact on uses by livestock. In: Herbicides and Vegetation Management Symp., Oregon State Univ., pp. 227-242.

Uses of herbicides which bring them into contact with livestock are reviewed briefly as is the fate of herbicides in soil and plants. Some data on the effects of herbicides on grazing and on forage residues are presented. Residues in animal tissues are discussed briefly. Herbicide toxicities and the effect of herbicides on the toxicity of plants to animals are reviewed. The author concludes that FDA, Fish and Wildlife, and other similar agencies exercise sufficient control over herbicides to prevent herbicide-induced livestock problems. 53 refs.

1392. Bailey, J.B., and J.E. Swift. 1968. Pesticide information and safety manual. Univ. California Agric. Ext. Service, 147 pp.

A review on safety and toxicity of a variety of pesticides, including four pages of herbicide toxicity data. 26 refs.

1393. Anon. 1969. Thalidomide effect from defoliants? Sci. Res. 4 (23): 11-12.

An annonymous summary of the report of the U.S. National Cancer Institute on the potential teratogenicity of 2,4-D and 2,4,5-T. The report, which summarises research by the Bionetics Research Labs. Inc. of Bethesda, Md., discusses the teratogenic activity of 53 pesticidal and industrial chemicals on mice and rats. The most conclusive results were those found for 2,4-D and 2,4,5-T. Gross malformation, cleft palates and eye deformities were found commonly in the young of female mice fed 2,4,5-T during pregnancy. It was concluded that while these results refer to the specific strains of mice use, and to very high dosage rates, the 2,4,5-T results are very significant and the 2,4-D results are probably significant. While no conclusions can be drawn concerning the effects on pregnant women, it is pointed out that thalidomide had less effect on mice than on humans.

1394. Courtney, K.D. and J.A. Moore. 1971. Teratology studies with 2,4,5-trichlorophenoxyacetic acid and 2,3,7,8,-tetrachlorodibenzo-P-dioxin. Toxiology and Appl. Pharmocol. 20: 396-403.

Studies were undertaken to determine teratogenicity of technical 2,4,5-T, analytical 2,4,5-T, and TCDD (dioxin) in three strains of mice (two pure and one random bred) and one strain of rat (random bred). Herbicides were either injected or administered by gastric intubation. Both herbicide compounds produced cleft palates and kidney malformations in all three strains of mice. Mixtures of the two compounds did not result in any potentiation of the teratogenic effect. 2,4,5-T was neither teratogenic nor fetotoxic to the rat strain used, while dioxin produced kidney anomalies. 11 refs.

1395. Pimentel, D. 1971. Ecological effects of pesticides on non-target species. Executive Office President, Office Sci. Tech., 4106-0029.

A comprehensive survey of insecticides, herbicides and fungicides in terms of toxicity for various types of animals (fish, birds, mammals, invertebrates, etc.) and persistence. There is a separate chapter dealing with pesticide residues in the environment. Each section has a substantial reference list, with 223 references in the herbicide chapter.

1396. Wilson, J.G. 1973. Teratological potential of 2,4,5-T. Industrial Vegetation Manage. 5L 10-13.

This is a discussion of the furore which arose over the teratogenicity of 2,4,5-T as suggested by the U.S. Scientific Advisory Committee. It is pointed out that the report of this committee was poorly presented in the media, giving the impression that 2,4,5-T is outstandingly teratogenic. The teratogenicity of several sommonly used medications is considered, and it is pointed out that all substances may be teratogenic under certain circumstances. The problem of the dioxin impurity of 2,4,5-T is discussed, and it is concluded that use of ' ' 2,4,5-T may be permitted again in the near future.

1397. Hill, E.V., and H. Carlisle. 1947. Toxicity of 2,4-dichlorophenoxy-acetic acid for experimental animals. J. Ind. Hygiene and Tox. 29 (2): 85-95.

1398. Grigsby, B.H., and E.D. Farwell. 1950. Some effects of herbicides on pasture and on grazing of livestock. Mich. Agr. Exp. Sta., Quart. Bull. 32: 378-385.

1399. Rudd, R.L., and R.E. Genelly. 1956. Pesticides: their use and toxicity in relation to wildlife. California Department of Fish and Game, Game Management Branch, Game Bull. 7: 149-209.

1400. Hodge, H.C., E.A. Maynard, W.L. Downs, and R.A. Coye. 1958. Chronic toxicity of 3(p-chlorophenyl)-1,1-dimethylurea (monuron). Arch. Ind. Health 17: 45-47.

1401. Hymas, T.A. 1958. Toxicity of herbicides to domestic animals. Agricultural Chemical Research, Dow Chemical Company (Midland, Michigan), ACD File No. H6-51.

1402. George, J.L. 1960. Some primary and secondary effects of herbicides on wildlife. In: Herbicides and their use in forestry, R.E. McDermott and W.R. Byrnes, eds., Pa. State Univ., For. Symp., pp. 40-73.

1403. Jukes, T.H., and C.B. Shaeffer. 1960. Antithyroid effect of amino-triazole. Science 132: 296-297.

1404. Radeleff, R.C., and R.C. Bushland. 1960. The toxicity of pesticides for livestock. In: The nature and fate of chemicals applied to soils, plants, and animals. U.S.D.A. ARS 20-9, pp. 134-160.

1405. Dalgaard-Mikkelsen, S., and E. Poulsen. 1962. Toxicology of herbicides. Pharm. Rev. 14 (2): 225-250.

1406. Vivier, P., and M. Nisbet. 1962. Toxicity of some herbicides, insecticides, and industrial wastes. U.S. Dept. of Health, Education and Welfare, Biological Problems in Water Pollution Seminar, 3.

1407. Edson, E.F., D.M. Sanderson, and D.N. Noahes. 1963. Acute toxicity data for pesticides. World Rev. of Pest Control 2 (3): 26-27.

1408. Fish and Wildlife Service. 1963. Pesticide wildlife studies. U.S. Dept. of Interior, Circ. 199.

1409. Gard, L.N., and C.E. Ferguson, Jr. 1963. Determination of micro amounts of isopropyl N-(3-chlorophenyl) carbamate (CIPC) in milk and urine excreted from dairy cows. J. Agr. Food Chem. 11: 234-236.

1410. Ware, G.W., and W.J. Brakel. 1963. Excretion of 3- -aniline and isopropyl-n-(3-chlorophenyl) carbamate (CIPC) in the milk and urine of dairy cows fed CIPC. J. Dairy Sci. 46: 120-123.

1411. Dow Chemical Company, Bio-products Dept. 1965. Chronic toxicity studies with Tordon herbicide. MG-117.

1412. Fisher, D.E., L.E. St. John, W.H. Gutenmann, D.G. Wagner, and D.J. Lisk. 1965. Fate of Banvel T, Tordon, and Trifluorilin in the dairy cow. J. Dairy Sci. 48 (12): 1711-1715.

1413. Lynn, G.E. 1965. A review of toxicological information on Tordon herbicides. Down to Earth 20 (4): 6-9.

1414. Klingman, D.L., C.H. Gordon, G. Yip, and H.P. Burchfield. 1966. Residues in the forage and in milk from cows grazing forage treated with esters of 2,4-D. Weeds 14: 164-167.

1415. Oliver, K.H. 1966. An ecological study on the effects of certain concentrations of cacodylic acid on selected fauna and flora. Department of the Army, Ft. Detrick, CDTL 45644.

1416. Oliver, K.H., G.H. Parsons, and C.T. Huffstetler. 1966. An ecological study on the effects of certain concentrations of cacodylic acid on selected fauna and flora. Air Proving Ground Center. Air Force Systems Command, USAF, Eglin Air Force Base, Florida, 25 pp.

1417. Stevens, M.A., and J.K. Walley. 1966. Tissue and milk residues arising from the ingestion of single doses of diaquat and paraquat by cattle. J. Sci. Food Agr. 17: 472-475.

1418. Ansul Chemical Company. 1967. Toxicological data-methanearsenic acid and dimethylarsinic acid (Compilation of toxicity reports). Chemical Products Div.

1419. Norris, L.A., M. Newton, and J. Zavitkovski. 1967. Atrazine residues in deer. Western Weed Control Conf., Res. Prog. Rept. 1967: 30-31.

1420. Condon, P.A. 1968. The toxicity of herbicides to mammals, aquatic life, soil microorganisms, beneficial insects and cultivated plants, 1950-65. U.S.D.A., National Agricultural Library, 161 pp.

1421. Newton, M., and L.A. Norris. 1968. Herbicide residues in blacktail deer from forests treated with 2,4,5-T and atrazine. Western Soc. Weed Sci. Proc. 1968: 32-34.

1422. McCollister, D.D., and M.L. Leng. 1969. Toxicology of picloram and safety evaluation of Tordon herbicides. Down to Earth 25: 5-10.

1423. Robens, J.F. 1969. Teratologic studies of carbaryl, diazinon, norea, disulfiram, and thiram in small laboratory animals. Toxicol. and Appl. Pharmacol. 15: 152-163.

1424. Anon. 1970. Another herbicide on the blacklist. Nature 226: 309-311.

1425. Courtney, K.D., D.W. Gaylor, M.D. Hogan, H.L. Falk, R.R. Bates, and I. Mitchell. 1970. Teratogenic evaluation of 2,4,5-T. Science 168: 864-866.

1426. Martynov, E.N. 1970. The effect of preparations of the 2,4-D group on wild warm-blooded animals. Lesn. Hoz. 1970 (6): 57-9.

1427. Tucker, R.K., and D.G. Crabtree. 1970. Handbook of toxicity of pesticides to wildlife. U.S. Fish Wildl. Serv., Bur. Sport Fish Wildl. Resource Publ, No. 84, 131 pp.

1428. Norris, L.A. 1971. Chemical brush control: Assessing the hazard. J. For. 69 (10): 715-720.

Cross references: 8, 37, 120, 306, 327, 355, 356, 357, 360, 361, 362, 367, 368, 369, 376, 377, 559, 610, 617, 637, 674, 696, 712, 718, 721, 723, 753, 776, 799, 805, 815, 822, 851, 1430, 1444, 1442, 1461, 1468, 1511, 1512.

C. Effects on fish

1429. Bond, C.E., R.H. Lewis, and J.L. Fryer. 1959. Toxicity of various herbicidal materials to fishes. USPHS, HEW Transactions of 1959 Seminar (Cincinnati, Ohio): 96-101.

Median tolerance limits are presented for three species of fish at 24 and 48 hours to 15 herbicides. There is a brief comment on each of the data. 11 refs.

1430. Anon. 1965. Effects of pesticides on fish and wildlife. Fish and Wildlife Service, Circular 226, 77 pp.

While this review of the Fish and Wildlife Service's 1964 research findings pertains largely to insecticides such as DDT, there is a section on Sport Fishery Investigations which lists LC_{50} data of herbicides and insecticides on fish and aquatic insects. EC_{50} data for herbicides, insecticides and fungicides are given for some marine organisms including phytoplankton and some invertebrates and vertebrates.

1431. Gilderhus, P.A. 1966. Some effects of sublethal concentrations of sodium arsenite on bluegills and the aquatic environment. Trans. Am. Fish Soc. 95: 289-296.

Bluegills were exposed to various concentrations of sodium arsenite in outdoor pools, and the affects on fish and aquatic invertebrates examined. At concentration of 4 ppm or more, survival and growth of the fish were reduced with immature fish showing greater sensitivity than adults. Bottom fauna and plankton were reduced in abundance or inhibited at the higher concentrations. 10 refs.

1432. Kenaga, E.E. 1969. Tordon herbicides-evaluation of safety to fish and birds. Down to Earth 25 (1): 5-9.

Data are presented on the toxicity of 9 Tordon formulations for 15 species of fish and 3 species of birds. It is concluded that 4-amino-3,5,6-trichloropicolinic acid and its salts exhibit low toxicity to fish, but that ester formulations and the addition of 2,4-D increases the toxicity. All derivations of picloram have very low acute toxicity to birds. Biological concentration of Tordon herbicides apparently does not occur. 27 refs.

1433. Juntunen, E.T., and L.A. Norris. 1972. Field application of herbicides -- Avoiding danger to fish. Agricultural Exp. Sta. Oregon State Univ., Special Report 354. 26 pp.

This manual presents acute toxicity data of herbicides for fish. There is a brief discussion of the modes of entry of herbicides into water bodies. 98 herbicides or different formulations thereof are listed according to whether they are acutely toxic to fish (laboratory TLm or LD_{50} values) at less than 1.0 ppm, at 1-5 ppm, at 5-15 ppm, or at greater than 15 ppm. It is interesting to note the variable toxicity of different formulations of the same herbicide. For example, 2,4-D may be toxic at less than 1.0 ppm or more than 15 ppm according to whether it is in the ester or amine form. 20 refs.

1434. Davis, J.T., and W.S. Hardcastle. 1959. Biological assay of herbicides for fish toxicity. Weeds 7L 397-404.

1435. Tomiyama, T., and K. Kawabe. 1962. The toxic effect of pentachlorophenate, a herbicide, on fishery organisms in coastal waters. I. The effect on certain fishes and a shrimp. Jap. Soc. Sci. Fish. Bull. 28: 379-382.

1436. Coakley, J.E., J.E. Campbell, and E.F. McFarren. 1964. Determination of butoxyethanol ester of 2,4-dichlorophenoxyacetic acid in shellfish and fish. J. Agri. Food Chem. 12: 262-265.

1437. Beasley, P.G., J.M. Lawrence, and H.H. Funderburk. 1965. The adsorption and distribution of C^{14}-labeled diquat in the goldfish, Carassius auratus (Linnaeus). Southern Weed Conf., Proc. 18: 581.

1438. Butler, P.A. 1965. Commercial fisheries investigations. In: Effects of Pesticides on Fish and Wildlife, Fish and Wildlife Service Cir. 226 (Research Findings): 65-77.

1439. Cope, O.B. 1965. Sport fishery investigations. In: The effects of pesticides on fish and wildlife. Fish and Wildlife Service, Circular 226, pp. 51-63.

1440. Hiltibran, R.C. 1967. Effects of some herbicides on fertilized fish eggs and fry. Trans. Amer. Fish. Soc. 96: 414-416.

1441. Alabaster, J.S. 1969. Survival of fish in 164 herbicides, insecticides, fungicides, wetting agents and miscellaneous substances. Int. Pest Contr. 11: 29-35.

Cross references: 558, 559, 632, 637, 674, 721, 712, 771, 773, 805, 911, 1071, 1072, 1390, 1395, 1402, 1406, 1408, 1413, 1420, 1422, 1461.

D. Herbicides and man

1442. Rowe, V.K. 1951. Health hazards associated with handling and use of herbicides. North Central Weed Control Conf., Proc. 8: 90-94.

The hazards of a number of herbicides for livestock and humans is reviewed. Herbicides discussed are sodium chlorate, borax, arsenicals, calcium cynamid, ammonium sulfamate, pentachlorophenol, dinitrophenols, 2,4-D, 2,4,5-T and MCP, sodium trichloroacetate, IPC, and methyl bromide. 13 refs.

1443. Goldstein, N.P., P.H. Jones, and J.R. Brown. 1959. Peripharal neuropathy after exposure to an ester of dichlorophenoxyacetic acid. J. Amer. Med. Assoc. 171: 1306-9.

Three cases of polyneuritis following heavy exposure (wetting of skin by herbicide without prompt washing) to an ester of 2,4-D are described in detail. Severe sensory and motor symptoms necessitated hospitalization and disability was protracted. Recovery was incomplete even after a lapse of several years. The herbicide apparently resulted in semi-permanent damage to the peripheral nervous systems. Great care in the handling of herbicides such as 2,4-D is advised. 5 refs.

1444. Norris, L.A. 1971. Studies of the safety of organic arsenical herbicides as precommercial thinning agents: a progress report. Proc. Precommercial thinning of coastal and intermountain forests in the Pacific Northwest. Washington State University. pp. 63-74.

A review of research projects being undertaken on various aspects of precommercial thinning using arsenical herbicides. Progress reports are presented for experiments on human health hazard, arsenic residues in cattle and small mammals, the effects on wildlife, and the behaviour of the herbicides in the forest environment. Of the various compounds, MSMA appeared to present the greatest problems. No arsenic residues were detected in streams leaving treated areas even though the arsenic was found to be quite mobile in the soil.

1445. Tarrant, R.F., and J. Allard. 1972. Arsenic levels in urine of forest workers applying silvicides. Arch. Environ. Health 24: 277-280.

Cacodylic acid and MSMA are widely used for pre-commercial thinning. This study examined arsenic uptake and excretion in workers using these materials. Urine samples were analysed for arsenic levels on Monday morning and Friday afternoon over a period of two months. Workers were found to absorb arsenic in spite of protective clothing and safety precautions. There was

no increase in urine arsenic over the two months after the first week, however, and urine levels were higher on Friday than Monday indicating active excretion. Most workers exceeded the recommended limit of 0.3 ppm arsenic in the urine on one or more occasions. 3 refs.

1446. Lehman, A.J. 1951. Chemicals in foods: a report to the Association of Food and Drug Officials on current developments. Part II. Pesticides. Quart. Bull. Assoc. Food and Drug Offic., U.S. 15 (4): 122-133.

1447. Goldstein, F. 1952. Cutaneous and intravenous toxicity of 'endothal' (disodium 3,6-endoxohexahydrophthalic acid). Fed. Proc. 11 (1). Part 1.

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1449. California Department of Public Health. 1962. Occupational disease in California attributed to pesticides and other agricultural chemicals. 1961. State Calif., Dept. Pub. Health. 28 pp.

1450. Desi, I., J. Sos, J. Olasz, F. Sule, and V. Markus. 1962. Nervous system effects of a chemical herbicide. Arch. Environ. Health. 4: 95-102.

1451. Anon. 1963. Report on use of pesticides. U.S. President's Sci. Advisory Comm. 26 pp.

1452. Berkley, M.C., and K.R. Magee. 1963. Neuropathy following exposure to a dimethyl amine salt of 2,4-D. Arch. Internal Med. 3: 133-134.

1453. Pinto, S.S., and B.M. Bennett. 1963. Effect of arsenic trioxide exposure on mortality. Arch. of Environ. Health 7: 583-591.

1454. Edson, E.F. 1964. Pesticides - a medical review. Jour. Royal Agri. Soc. England 125:

1455. Lehman, A.J. 1965. Appraisal of the Safety of Chemicals in Foods, Drugs, and Cosmetics. Editorial Committee of the Association of Food and Drug Officials of the U.S., 97.

1456. Bullivant, C.M. 1966. Accidental poisoning by paraquat: report of two cases in man. Brit. Med. J. 1: 1272-1273.

1457. Clark, D.G., T.F. McElligott, and E.W. Hurst. 1966. The toxicity of paraquat. Brit. J. Int. Med. 23: 126.

1458. Almog, C., and E. Tal. 1967. Death from paraquat after subcutaneous injection. Brit. Med. J. 3 (5567): 721.

1459. Hayes, W.J., Jr. 1967. Pesticides and human toxicity. U.S. HEW, Public Health Service Communicable Disease Center, MS 303.

1460. Frost, D.V. 1969. Arsenic and cancer. Letter to the editor. J. of Allergy. 44 (5): 320.

1461. Way, J.M. 1969. Toxicity and hazards to man, domestic animals, and wildlife from some commonly used auxin herbicides. Residue Reviews 26: 37-62.

1462. Epstein, S.S. 1970. A family likeness. Environment 12: 16-25.

1463. Johnson, J.E. 1970. Testimony before subcommittee on energy, natural resources and the environment of the committee on commerce, Apr. 7 & 15, 1970. In: Effects of 2,4,5-T on man and the environment. U.S. Congr. Ser. 91-60. pp. 360-404.

Cross references: 412, 532, 559, 632, 637, 712, 724, 729, 753, 1036, 1043, 1087, 1392, 1393, 1406, 1424.

VII. DEGRADATION OF HERBICIDES

A. Degradation by microorganisms

1464. Evans, W.C., and B.S.W. Smith. 1954. The photochemical inactivation and microbial metabolism of the chlorophenoxyacetic acid herbicides. Biochem. J. 57: XXX.

Describes a small gram-negative motile rod isolated from conifer forest litter which will grow in a 2,4-D (up to 0.1%) mineral salt medium. It appears capable of decomposing the 2,4-D. 8 refs.

1465. Rogoff, M.H., and J.J. Reid. 1956. Bacterial decomposition of 2,4-dichlorophenoxyacetic acid. J. Bact. 71: 303-307.

This study isolated cultures of bacteria from agricultural soils and tested their ability to decompose 2,4-D. Decomposition was attributed to a species of the genus Corynebacterium, which are quite numerous in soils and have been implicated in the attack of various aromatic compounds. The isolate was able to decompose 1000 ppm 2,4-D in 3-5 days, the ring being ruptured followed by complete destruction. 13 refs.

1466. Ashton, F.M. 1963. Fate of amitrole in soil. Weeds 11 (3): 167-170.

The bioactivity and persistence of amitrole is known to be affected by temperature, clay content, soil moisture, exchange capacity, levels of metalic ions in the soil, and by soil sterilization. ^{14}C-labelled amitrole was added to sterilized (autoclaved) and unsterilized sandy loam soil (Davis, California). Adsorption and persistence (at 80°F) were measured using organic extraction, chromatography, autoradiography, and planchet counting. Experiments of 96 hours and 59 days were conducted to quantify short and long term degradation. In the non-sterile soil, microbial action initiated decomposition within hours, 50% being decomposed after 28 days. In the sterilized soil there was very little decomposition. Both the amitrole and its unidentified degradation products were tenaciously held in unsterilised as compared to sterilised soil. Amitrole was found to form complexes with nickel, cobalt and copper ions. 8 refs.

1467. Bounds, H.C., and A. Colmer. 1965. Detoxification of some herbicides by streptomyces. Weeds 13 (3): 249-252.

A diverse range of Streptomyces species was isolated from agricultural soils in Louisiana where seven chlorinated herbicides had been used in weed control. Some were able to germinate at 1,000 times the recommended field rates for some of the herbicides. A cucumber seed bioassay showed that one species (S. viridochromogenes) detoxified 2,4-D, silvex, fenac and dalapon, but little detoxification was shown with CDAA, CIPC, or 2,4,5-T. Manometric studies showed that the streptomycete was capable of rapid adaptation to 2,4-D, 2,4,5-T, and silvex, but not to 2,4-dichlorophenol, a proposed intermediate of 2,4-D metabolism. 9 refs.

1468. Goring, C.A.I. 1966. Tordon in the environment. Dow Chemical Company, Bioproducts Research Laboratory, Walnut Creek, California, 12 pp.

A review of the physical properties, degradation in plants, soils and water, fate in animals, persistence and movement in soils and water, sorption in soils, and toxicity of tordon. A rather brief treatment, but provides a summary of some major points of interest concerning tordon. No refs.

1469. Kaufman, D.D. 1966. Relations between structure of certain pesticides and susceptibility to decomposition by soil microorganisms. In: Pesticides and their effects on soils and water. Wisconsin Soil Sci. Soc. Amer., A.S.A. Special Publ. 8: 85.

Reviews the relationship between the number, type, and position of chemical substituents on the resistance of aliphatic and aromatic pesticides to microbial decomposition. Microbial decomposition tends to decrease as the number of halogens on the molecule increases, and is affected by the position of these halogens. Results of studies of these effects are reported. 16 refs.

1470. Norris, L.A. 1966. Degradation of 2,4-D and 2,4,5-T in forest litter. J. Forestry 64 (7): 475-476.

^{14}C-labeled 2,4-D and 2,4,5-T were incubated with forest litter from an alder stand in western Oregon. Degradation was measured by the evolution of $^{14}CO_2$. More than 89% of the applied 2,4-D was degraded in 315 hours as compared with 23% of 2,4,5-T; it was 690 hours before 53% of the 2,4,5-T was decomposed. The agents responsible for the degradation of 2,4-D increasingly adapted to its use as a substrate with time.

1471. Hamaker, J.W., C.R. Youngson, and C.A.I. Goring. 1968. Rate of detoxification of 4-amino-3,5,6-trichloropicolinic acid in soil. Weed Res. 8: 46-57.

4-Amino-3,5,6-trichloropicolinic acid was incubated with 13 different Californian or Texan soils for up to two years at various concentrations. Cucumber bioassay was used. Losses varied from complete to non-measurable by this method; the lower the initial concentration, the greater the percentage loss. Half order and Michaelis-Menten kinetics were found to describe the observed detoxification. 57 refs.

1472. Norris, L.A. 1968. Degradation of herbicides in the forest floor. In: Tree Growth and Forest Soils, Proc. Third N. American For. Soils Conf., Oregon State Univ., Corvallis, pp. 397-411.

This paper is largely a review of published material but contains some original data. The relative rates of degradation of 2,4-D, 2,4,5-T, amitrole and picloram in forest floors are considered, as are the effects of the type of forest floor and the formulation. Experiments on the effects of DDT, serin, phosphamidon on rates of degradation are described. Degradation of 2,4-D was independent of any other material except DDT which may accelerate the process slightly. Picloram and 2,4,5-T may cause an initial slowing, but there was no overall effect. The rate of breakdown of 2,4,5-T may be accelerated for 60 days by the presence of 2,4-D, but over 4 months there is no effect. Amitrole degradation was unaffected by the presence of the other substances, as was the case for picloram. Amitrole degrades as rapidly or more rapidly than 2,4-D and is abundantly degraded even in steam-sterilized material. Degradation of 2,4-D, 2,4,5-T, and amitrole appear to follow first order kinetics, although this may change over time. Mixed order kinetics may reflect changes in availability of herbicide or efficiency of its utilization by microorganisms. 27 refs.

1473. Kearney, P.C., and D.D. Kaufman (Eds.) 1969. Degradation of herbicides. Marcel Dekker Inc., N.Y., 394 pp.

Individual chapters by 17 authors deal with the degradation of phenoxyalkanoic acids, s-triazines, the substituted ureas, methyl- and phenylcarbamates, thiolcarbamates, chloroacetamides, amitrole, the chlorinated aliphatic acids, trifluralin and related compounds, diquat and paraquat, and the benzoic acid herbicides. A final chapter discusses photodecomposition of herbicides. There is an author and subject index.

1474. Murray, D.S., W.L. Rieck, and J.Q. Lynd. 1969. Microbial degradation of five substituted urea herbicides. Weed Sci. 17: 52-55.

Studies were made of the phytotoxicity of five substituted urea herbicides to three species of Aspergillus. The rate of degradation of these materials by the species in culture broth was quantified using oat seedlings as a bioassay. Significant differences in rates were found between herbicides and between the three fungi. The effects of variations in the nitrogen and carbon content of the soil on phytotoxicity and rates of degradation were examined. Phytotoxicity decreased as organic nitrogen levels increased, except with monuron. Fenuron plus high levels of organic nitrogen were found to stimulate plant production. 12 refs.

1475. Murray, D.S., W.L. Rieck, and J.Q. Lynd. 1970. Utilization of methylthio-s-triazine for growth of soil fungi. Appl. Microbiol. 19: 11-13.

Three species of Aspergillus were found to utilize methylthio-s-Triazine (prometryne) as a sulphur nutrient source. These and other common soil inhabiting fungi were cultured on broth media containing various levels of this herbicide. The effect of additional sulphur sources on degradation by Aspergillus species was also investigated. Thin-layer chromatography was used for detection of residues. All fungal isolates used exhibited high tolerance for prometryne at concentrations up to 1 mg/ml in broth media. 9 refs.

1476. Newman, A.S., and A.G. Norman. 1947. Effect of soil microorganisms on the persistence of plant growth regulators in the soil. Jour. Bact. 54: 37-38.

1477. Audus, L.J. 1951. The biological detoxication of hormone herbicides in soil. Plant and Soil 3: 170-192.

1478. Audus, L.J. 1952. Decomposition of 2,4-dichlorophenoxyacetic acid and 2-methyl-4-chlorophenoxyacetic acid in the soil. Jour. Sci. Food Agri. 3: 268-274.

1479. Jensen, H.L., and H.I. Petersen. 1952. Decomposition of hormone herbicides by bacteria. Acta Agr. Scand. 2: 215-231.

1480. Walker, R.L., and A.S. Newman. 1956. Microbial decomposition of 2,4-dichlorophenoxyacetic acid. Appl. Microbiol. 4 (4): 201-206.

1481. Bondarenko, D.D. 1958. Decomposition of amitrol in soil. North Central Weed Control Conf., Proc. 15: 5-6.

1482. Newman, A.S., and J.R. Thomas. 1959. Decomposition of 2,4-dichlorophenoxyacetic acid in soil and liquid media. Soil Sci. Soc. Amer., Proc. 14: 160-164.

1483. Andus, L.J. 1960. Microbiological breakdown of herbicides in soils. Herbicides and the Soil. E.K. Woodford and G.R. Sager, eds., Blackwell Scientific Publications, Oxford, pp. 1-19.

1484. Bell, G.R. 1960. Studies on a soil Achromobacter species which degrades 2,4-dichlorophenoxyacetic acid. Can. J. Microbiol. 6: 1325

1485. Hirsch, P., and M. Alexander. 1960. Microbial decomposition of halogenated propionic and acetic acids. Can. J. Microbiol. 6: 241-249.

1486. Reid, J.J. 1960. Bacterial decomposition of herbicides. North Central Weed Control Conf., Proc. 14: 19-30.

1487. Alexander, M., and M.I. Aleem. 1961. Effect of chemical structure on microbial decomposition of aromatic herbicides. J. Agr. Food Chem. 9: 45.

1488. Evans, W.C., J.K. Gaunt, and J.I. Davis. 1961. The metabolism of chlorophenoxyacetic acid herbicides by soil micro-organisms. Congr. Internat. Biochem. 5: 306.

1489. Faulkner, J.K., and D. Woodcock. 1961. Metabolism of chlorophenoxyacetic acids by *Aspergillus niger*. Chem. Ind. 34: 1366.

1490. Winston, S.W., Jr., and P.M. Ritty. 1961. What happens to phenoxyherbicides when applied to a watershed area. Northeastern Weed Control Conf., Proc. 15: 396-401.

1491. Ashton, F.M., and O.A. Leonard. 1962. Breakdown of amino-trizole in soil. Proc. 14th Calif. Weed Conf. 1962: 87-88.

1492. Riepma, P. 1962. Preliminary observations on the breakdown of 3-amino-1,2,4-triazole. Weed Res. 2: 41-50.

1493. Thiegs, B.J. 1962. Microbial decomposition of herbicides. Down to Earth 18 (2): 7-10.

1494. Martin, J.P. 1963. Influence of pesticide residues on soil microbiological and chemical properties. Residue Rev. 4: 96-129.

1495. Bozarth, G.A., H.H. Funderburk, E.A. Curl, and D.E. Davis. 1965. Preliminary studies on the degradation of paraquat by soil microorganisms. Proc. 18th Southern Weed Control Conf. 18: 615.

1496. Couch, R.W., J.V. Gramlich, D.E. Davis, and H.H. Funderburk, Jr. 1965. The metabolism of atrazine and simazine by soil fungi. Proc. Southern Weed Conf. 18: 623-631.

1497. Kaufman, D.D., P.C. Kearney, and T.J. Sheets. 1965. Microbial degradation of simazine. J. Agr. Food Chem. 13: 238-242.

1498. Okey, R.W., and R.A. Bogan. 1965. Apparent involvement of electronic mechanism in limiting the microbial metabolism of pesticides. J. Water Pollut. Control Fed. 37: 692.

1499. Alexander, M. 1966. Biodegradation of pesticides. In: Pesticides and their effects on soils and water. Soil Sci. Soc. Amer., A.S.A. special publ. 8: 78.

1500. Baldwin, B.C., M.F. Bray, and M.J. Geoghegan. 1966. The microbial decomposition of paraquat. Biochem. J. 101: 15.

1501. McCormick, L.L., and A.E. Hiltbold. 1966. Microbiological decomposition of atrazine and diuron in soil. Weeds 14: 77-82.

1502. Grover, R. 1967. Studies on the degradation of 4-amino-3,5,6-trichloropicolinic acid in soil. Weed Res. 7: 61-67.

1503. Norris, L.A., and D. Greiner. 1967. The degradation of 2,4-D in forest litter. Bull. Environ. Cont. Tox. 2 (2): 65-74.

1504. Schwartz, H.G., Jr. 1967. Microbial degradation of pesticides in aqueous solution. J. Water Poll. Contr. Fed. 39: 1701-1714.

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1508. Hemmett, R.V., Jr., and S.D. Faust. 1969. Biodegradation kinetics of 2,4-dichlorophenoxyacetic acid by aquatic microorganisms. Residue Rev. 29: 191-207.

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1510. Norris, L.A. 1970. Degradation of Herbicides in the Forest Floor. In: Tree Growth and Forest Soils, C.T. Youngberg and C.B. Davey, eds. Oregon State University Press, pp. 397-411.

Cross references: 45, 154, 514, 558, 585, 608, 616, 632, 651, 831, 850, 851, 856, 857, 861, 862, 866, 881, 882, 883, 884, 886, 889, 894, 905, 911, 944, 947, 983, 989, 1003, 1004, 1019, 1020, 1026, 1240, 1514, 1535, 1540, 1593.

B. Degradation by animals

1511. Clark, D.E., J.E. Young, R.L. Younger, L.M. Hunt and J.K. McLaren. 1964. The fate of 2,4-dichlorophenoxyacetic acid in sheep. J. Agric. & Food Chem. 12: 43-45.

^{14}C-labeled 2,4-D was administered orally to a yearling ewe at a dose calculated to approximate the daily dose a sheep would ingest from grazing herbicide-treated pasture. Continuous urine samples were obtained using a catheter. Blood and feces were sampled, and on the fourth day the ewe was sacrificed and various tissues analysed. Analysis was accomplished using a thin-window GM counter, and paper chromatography and electrophoresis. Approximately 96% of the 2,4-D was excreted unchanged in the urine within 72 hours. Less than 1.4% was found in the feces over the same time period. Very little radioactivity was found in edible tissues, and it was concluded that 2,4-D is excreted unchanged by sheep. 8 refs.

1512. Fang, S.C., M. George, and T.C. Yu. 1964. Metabolism of 3-amino 1,2,4-triazole-5-C^{14} by rats. J. Agr. Food Chem. 12 (3): 219-223.

Cross references: 1472.

C. Non-biological degradation

1513. Crosby, D.G., and H.O. Tutass. 1966. Photo decomposition of 2,4-dichlorophenoxyacetic acid. J. Agr. Food Chem. 14: 596-599.

2,4-dichlorophenoxyacetic acid was dissolved in water with sodium bicarbonate and irradiated with ultraviolet light (254 mm) or sunlight. Ultimately, all of the 2,4-D was converted into humic acid. Initial conversion to 2,4-dichlorophenol was rapid (50% loss in 50 minutes at pH 7.0) Photodecomposition results in an acidifcation of the solution. Sunlight produced a similar rate of degradation to that of U.V. 10 refs.

1514. Kaufman, D.D., J.R. Plimmer, P.C. Kearney, J. Blake, and F.S. Guardia. 1968. Chemical versus microbial decomposition of amitrole in soil. Weed Sci. 16: 266-272.

This study examined degradation of ^{14}C-labeled amitrole in 3 agricultural soils (a sandy loam, a silty clay loam, and a muck soil) by liquid-scintiallation counting of $^{14}CO_2$. The effects on decomposition of soil sterilization by autoclaving, potassium ozide, etylene oxide, and dry heat, and of soil aeration and organic or inorganic amendments were examined for the 3 soils. Amitrole degradation was also examined in 2 different free radical systems (Fenton's reagent and an ascorbic acid-cupric sulphate-oxygen system). The observed temporal pattern of degradation and the lack of correlation between degradation and microbial activity was more suggestive of chemical than microbial processes. Organic soil amendments increased microbial activity but depressed amitrole degradation. Amitrole degradation occurred at a 40-50% reduced level in KN_3 and FtO sterilised soils but was inhibited in autoclaved soil although the degree of sterilisation was almost uniform. Very little degradation occurred in successfully re-inoculated autoclaved soils. The free radical systems were found to actively degrade amitrole and such systems are known to occur in soils: autoclaving may alter such naturally occurring systems. Addition of mellatic salts inhibited degradation on the silt clay and clay loam, but addition of $FeSO_4$ increased degradation in the muck soil. Combinations of different amendments produced variable effects on degradation leading to the conclusion that microbes are at least indirectly involved in amitrole degradation. Degradation was inhibited in an N_2 atmosphere indicating that degradation is largely an oxidative process. It is concluded that in the soils studied, amitrole degradation is an oxidative chemical process involving free radical systems whose formation may involve microbial activity. Conditions favouring microbial activity also favour increased chemical activity in soils. 24 refs.

1515. Russell, J.D., M. Cruz, J.L. White, G.W. Bailey, W.R. Payne, Jr., J.D. Pope, Jr., and J.I. Teasley. 1968. Mode of chemical degradation of s-triazines by Montmorillonite. Science 160: 1340-1342.

The concept that the major degradation factor of the commonly used s-triazines is microbial action is challenged with the support of published data. Hydroxy analogs of s-triazines have been identified as the major non-biological degradation product. Spectroscopic (infrared) and NMR evidence is presented that chemical hydrolysis of s-triazines occurs in the presence of montmorillonite clay of less than 2-microns diameter. Protonation of the herbicide occurs even when the cation exchange sites are occupied by metallic ions. The adsorbed hydrolytic degradation product was not found to be the hydroxy analog, but the keto form of the protonated hydroxy species. This cationic form is held tightly by the clay which may restrict the movement of the degraded herbicide within the soil profile. The interaction between montmorillonite and herbicides is sensitive to the surface acidity of the clay particles. 15 refs.

1516. Hamilton, R.H., and R.J. Aldrich. 1953. Failure of light activated riboflavin to counteract the growth inhibition of 2 benzoic acid derivatives. Weeds 2: 202-203.

1517. Bell, G.R. 1956. On the photochemical degradation of 2,4-dichlorophenoxyacetic acid and structurally related compounds in the presence and absence of riboflavin. Bot. Gaz. 118: 133-136.

1518. Castelfranco, P., A. Oppenheim, and S. Yamaguchi. 1963. Riboflavin-mediated photodecomposition of amitrole in relation to chlorosis. Weeds 11: 111-115.

1519. Jordan, L.S., J.D. Mann, and B.E. Day. 1965. Effects of ultra violet light on herbicides. Weeds 13: 43-46.

1520. Slade, P. 1966. The fate of paraquat applied to plants. Weed Res. 6: 158-167.

1521. Hance, R.J. 1967. Decomposition of herbicides in the soil by non-biological chemical processes. J. Sci. Food Agr. 18: 544-547.

1522. Plimmer, J.R., P.C. Kearney, D.D. Kaufman, and F.S. Guardia. 1967. Amitrole decomposition by free radical-generating systems and by soils. Jour. Agr. Food Chem. 15: 996-999.

1523. Hall, R.C., C.S. Giam, and M.G. Merkle. 1968. The photolytic degradation of picloram. Weed Res. 8: 292-297.

1524. Crosby, D.G., and Ming-Yu Li. 1969. Herbicide photodecomposition. In: Degradation of Herbicides. Marcel Dekker, New York. pp. 321-364.

1525. Hance, R.J. 1969. Further observations on the decomposition of herbicides in soil. J. Sci. Food Agr. 20: 144-145.

Cross references: 154, 451, 558, 566, 608, 616, 643, 847, 850, 851, 862, 881, 883, 889, 894, 903, 911, 917, 925, 936, 952, 1020, 1328, 1468, 1472, 1473, 1510.

D. Degradation by plants

1526. Castelfranco, P., C.L. Foy, and D.B. Deutsch. 1961. Nonenzymatic detoxification of 2-chloro-4,6-bis(ethylamino)-s-triazine (simazine) by extracts of Zea Mays. Weeds 9: 580-591.

Sap pressed from corn and oats seedlings was effective in converting simazine to the corresponding 2-hydroxy analogue. The active constituent in the crude extract is destroyed by ashing and boiling, although boiling after cleanup by acetone precipitation causes no loss of activity: it is concluded that the active constituent is not a protein. Sap from a susceptible species (Avena) did not detoxify simazine. 7 refs.

1527. Basler, E. 1964. The decarboxylation of phenoxyacetic acid herbicides by excised leaves of woody plants. Weeds 12: 14-18.

Resistance to herbicides by plants may be related to rapid detoxification. Conflicting literature on the relationship between detoxification and decarboxylation of phenoxyacetic acid herbicides is reviewed. This paper reports studies of decarboxylation rates of 2,4-D, 2C4F, and 2,4,5-T by excised leaves of 5 tree species using evaluation of $^{14}CO_2$ as a meausre of decomposition. 2,4,5-T showed lowest rates of decarboxylation by black jack oak and is known to be the most toxic of the three herbicides to this species. 2C4F was decarboxylated most rapidly by this species. However, there is not a good correlation between decarboxylation and toxicity of 2,4-D in the other species studied. 9 refs.

1528. Shimabukuro, R.H. 1967. Atrazine metabolism and herbicidal selectivity. Plant Physiol. 42: 1269-1276.

Resistance of some plants to atrazine and simazine appears to be related to their ability to convert them to their hydroxy derivatives. This ability is probably non-enzymatic and is sometimes but not always associated with the presence of benzoxazinone. In other species, resistance is related to dealkylation. This study examined metabolic degradation of atrazine in species of differing susceptibility. All species were found to be able to metabolise atrazine initially by N-dealkylation. Those plants containing benzoxazinone also metabolised atrazine initially by hydrolysis to hydroxyatrazine. Subsequent metabolism to both pathways converted atrazine to more polar compounds and eventually into a methanol-insoluble residue. Both pathways result in detoxification. Hydroxylation leads directly to a non-phytotix derivatice while dealkylation leads to detoxification through one or more partially detoxified stable intermediaries. Resistance to atrazine relates to the rate and pathway of metabolism. 24 refs.

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Cross references: 154, 598, 608, 614, 618, 622, 624, 713, 756, 850, 851, 883, 911, 1203, 1205, 1208, 1237, 1238, 1243, 1266, 1267, 1272, 1287, 1290, 1295, 1297, 1301, 1307, 1316, 1317, 1318, 1332, 1344, 1351, 1377, 1378.

VIII. HERBICIDES AND CELLS

A. Effects on metabolic processes

1545. Sund, K.A., and H.N. Little. 1960. Effect of 3-amino-1,2,4-triazole on the synthesis of riboflavin. Science 132: 622.

Evidence is presented from a laboratory experiment with yeast, peas and corn that 3-amino-1,2,4-triazole inhibits the synthesis of riboflavin. Earlier work had shown that the phytotoxicity of this herbicide could be reduced by the addition of riboflavin. 4 refs.

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This study examined the effect of various herbicides on the photochemical activity of isolated turnip chloroplasts, investigated the relationship of this inhibition to the structural configuration of the herbicides, and sought correlations between degree of chloroplast inhibition and known phytotoxicity. Differences in the sensitivity of chloroplasts from different species to herbicides, and the ability of chloroplasts to recover their photolytic activity following herbicide treatment was also examined. There was a close agreement between the ability of several phenylureas, s-triazines, and chlorinated phoxyacetic acids to inhibit Hill's reaction and their phytotoxicities: such a relationship was not shown by the chlorinated benzoic acids. Chloroplasts from three species varying in resistance were equally sensitive to the herbicides, so that the relative sensitivities of the intact plants to the herbicides cannot be explained in terms of inhibition of the Hill reaction. Chloroplasts exposed to herbicides in the dark recovered their photolytic abilities when the herbicides were removed by washing: no such recovery occurred in the light, when the herbicides produced irreversible changes, with the exception of simazine. 56 refs.

1547. Lembeck, W.J. and A.R. Colmer. 1967. Effect of herbicides on cellulose decomposition by Sporocytophaga myxococcoides. Appl. Microbiol. 15: 300-303.

The effects of 14 herbicides (Atrazine, Simazine, Dacthal, Diuron, Amiben, Banvel-D, Banvel-T, 2,3,6-TBA, Dieryl, Maleic hydrozide, Stam F-34, Zytron, Fenac, and Dalapon) on cellulose decomposition by Sporocytophaga myxococcoides (a bacterium) were studied in two different media. Amiben at concentrations greater than 480 ppm delayed cellulotic activity, and at 4800 ppm completely inhibited it. Excess quantities of Atrazine and Simazine failed to elicit any effects while Banvel-D and T were mildly inhibitory at 96 ppm; at 960 ppm they were totally inhibitory, 2,3,6-TBA behaved similarly. Neither Dacthal nor Diuron produced any effects, even in excess, while Dicryl delayed cellulotic activity by 24 hours at 5 ppm, 48 hours at 9 ppm, while an excess (14 ppm) delayed it for 3 days. Maleic hydrozide was only mildly inhibitory at 200 ppm but completely at 300 ppm. Stam-F-34 exhibited slight inhibition at 5 ppm and complete inhibition at 50 ppm. Dalapon exhibited little response up at low levels: at 500 ppm and above considerable inhibition was evident. Both Fenac and Zytron exhibited the highest rates of inhibition. It was concluded that only Zytron has any inhibitory effects at concentrations found in normal field applications. 6 refs.

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Cross references: 514, 589, 626, 637, 965, 970, 976, 979, 989, 994, 996, 1000, 1002, 1004, 1007, 1105, 1107, 1144, 1167, 1494, 1501.

B. Cytological effects

1608. Muhling, G.N., J. Van't Hof, G.B. Wilson, and B.H. Grigsby. 1960. Cytological effects of herbicidal substituted phenols. Weeds 8 (2): 173-181.

This study was concerned with whether or not the cytological effects of substituted phenol herbicides are such to suggest subtle biological hazards to organisms apparently not affected morphologically. Pea seeds were germinated and grown for 8-12 hours with their roots in herbicide solution. Dividing cells were examined cytologically for effects of the herbicide. A variety of cytological effects were observed, including effects on the colchicine reaction, the prophase poison reaction and chromosome fragmentation, and inhibition of cell division. There is a discussion of the literature on the effects of phenol herbicides on such things as oxidation-phosphorylation systems in both plants and animals. 20 refs.

1609. Jackson, W.T. 1961. Effect of 3-amino-1,2,4-triazole and L-Histidine on rate of elongation of root hairs of Agrostis alba. Weeds 9: 437-442.

The rate of elongation of root hairs of Agrostis alba was unaffected by amitrole at 10^{-5}-10^{-1} M concentrations for the first hour, but there was a reduction in the second hour by concentrations of 10^{-2}-10^{-1}. Additions of l-histidine restored and increased the growth rate. It is concluded that in addition to amitrole's known effects on inhibition of chlorophyll formation, it blocks one or more steps in the synthesis of l-histidine. 11 refs.

1610. Bachelard, E.P., and R.D. Ayling. 1971. The effects of picloram and 2,4-D on plant cell membranes. Weed Research 11 (1): 31-36.

Sections of Pinus radiata needles and Eucalyptus viminalis leaves were floated in aqueous solutions containing either picloram or picloram plus 2,4-D. Sections of the needles and leaves were examined daily for five days, and the electrical resistance of the sections for up to 72 hours. Picloram plus 2,4-D caused severe shrinkage of the protoplasts of all cells of P. radiata, and the electrical measurements indicated a breakdown of plasmalemma within four to eight hours of treatment. Picloram alone failed to duplicate these effects. In Eucalyptus, on the other hand, chloroplasts in leaf discs and the integrity of cell membranes in stem tips were disrupted equally by picloram alone or by picloram plus 2,4-D. 8 refs.

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Cross references: 669, 671, 784, 787, 789, 790, 796, 797, 801, 1089, 1090, 1106, 1245, 1548.

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