evident in both varieties in January and increased in severity as the season advanced. It was most pronounced, becoming almost black, where abrasions or bruising occurred at harvest time. The Yellow Jersey roots shown in Figure 3 were photographed in early June. Also of less importance was a yellow or orange fungus that sometimes develops on the surface of the roots. This gave the appearance of a seepage or exudation of yellow color from the sweet potatoes.

Sprouting was not of major importance in any of the stored lots. During the second season, there appeared to be slightly more sprouting at the highest humidity than at the lowest, but the difference was not great. In a few instances feeder roots developed at the highest humidity.

Conclusions

Humidity of storage had relatively little direct effect on the increase in carotene or the decrease in ascorbic acid during the storage period. It was of major importance in determining loss of weight in sweet potatoes. Low humidity caused excessive loss in weight, and tended to hasten internal breakdown and shorten the storage life. High humidity caused an increase in moisture content of the roots during storage, but no additional decay. A humidity of 95% or above is likely to cause surface discoloration and poor appearance. A relative humidity of 85 to 90% would appear to be optimum for sweet potato storage.

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PESTICIDES LITERATURE

The Literature of Pesticide Toxicology

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There can be no simple, easily summarized statement of the toxicology of a pesticidal material. Both quantitative and qualitative information is required, species differences must be defined, and effects of combination with other materials should be included. Until the conditions of use are known, no amount of toxicological information will allow estimation of safety. Four classes of people require literature on the toxicology of this chemically heterogeneous group: those who develop new materials, those who guard occupational health, those who protect public health, and those who treat persons injured by an excess. Some specific sources of information for each group are suggested.

It is an illusion to expect to obtain from the literature a brief statement of the toxicology of a pesticide. To be useful, a summary must be complex and many faceted. Among the facts required are the amounts tolerated by man and other species which may come in contact with the material, estimated both for a single contact and for a contact repeated daily, and for all the kinds of contact which are probable. A statement of the biochemical and pharmacological actions of the material in the body is required, as well as of its pathological effects upon the body. The nature of injury from amounts greater than those tolerated must be described and methods for recognizing, forestalling, and curing the effects of injury are required. The effects of the pesticide acting in combination with other materials should be included. The effect upon resistance to the material of the manifold deficiencies, weaknesses, and excesses among the individuals in the population should be stated.

And if it is an illusion to hope that the literature can summarize briefly the toxicology of a pesticide, it is even more illusory to expect to find there any brief sound statement of the safety of its use. Until the conditions of use are known, no amount of toxicological information will allow estimation of safety. One must know the frequency, ways, and quantities in which contact with the pesticide will be involved in its production, formulation, transportation, and application, and the frequency, ways, and amounts in which the public will come in contact with materials bearing residues of the pesticides. In order to interpret the toxicological data in terms of safety or hazard, one must compare the amounts of the pesticide in contact and the frequency of contact with the tolerated amounts defined by the toxicologist. One must consider the amounts of other materials which may influence the effects of the pesticide. One must weigh the nature of the effects of excess, the ease of diagnosis of injury, the promptness of recovery from injury, and the availability of an effective antidote to treat accidental poisoning.

The conclusion that a pesticide is safe

in use can rest only upon judgments, usually based upon animal experiment. And even after it is being used by the public, it is next to impossible, although no one would say it would not be desirable, to verify the prediction of its safety by studies among the human users and a control group of nonusers.

Pitfalls in Toxicological Data

It is difficult to interpret and compare reports in the literature upon the results of toxicological study. There are as yet no standard experimental methods. It is not always appreciated how great a deviation may result from a difference in methods which may seem not worth describing. For about 10 years a particular laboratory could not understand why its determination of acute toxicity appeared never to agree closely with values obtained by others. Extensive observation of actual operations by other workers, prolonged discussion of methods, and exchange of samples failed to reveal the reason for lack of agreement. It was facetiously ascribed to a difference in altitude above sea level. Finally, by accident, it was found that the one laboratory administered single doses to animals which had access to food at all times and hence whose stomachs contained food when the dose was intubated. Other laboratories deprived their animals of food for some 18 hours before intubation, and the dose entered an empty stomach. Each party had considered its own practice the perfectly obvious and proper way to work, and had never mentioned it. This one detail of technique may account for a difference of 20% or more in LD_{50} values.

Aside from the obvious one of species studied, other points of technique which are particularly important in acute toxicity determination are the strain, age, and sex of the animals used, the composition of the diet, the dilution of the chemical administered, the solvent used, and the length of time surviving animals are observed after intubation of the dose. Any one of these may cause a major difference in the numerical value of the acute toxicity, and any one may well be inadvertently omitted in publishing the results. If the literature indicates that one laboratory found the LD_{50} of a pesticide to be 1.0 gram per kg., and another found the LD_{50} of a second product to be 1.5 grams per kg., is the second actually less acutely toxic than the first? Usually it is impossible to determine without retesting the two at one time in one laboratory under one set of conditions. Happily, no crucial decision is usually made on the basis of acute toxicity, but the difference cited above has been far exceeded in actual practice. The most striking example is a difference of 1000 times in the toxicity of a particular batch of a particular pesticide, later found to be caused by a hypersensitivity developed unwittingly in the inbred rat strain used in one laboratory.

The results of chronic toxicity tests are also influenced to a great extent by apparently minor differences in technique. These results are more important than those of acute toxicity determinations in judging safety in use. The statement that "rats were not affected by 1% in their diet" is almost meaningless until one knows more details of the study. Here is a paraphrase of a situation found in the literature. One laboratory reported no effect from 2% of a material in the rat diet during 2 years and another found some degeneration of testicular tubular epithelium from 1% of an almost identical material. The first laboratory stated that it studied pathology but did not name the organs looked at. It is impossible to determine from what was published whether one material was more than twice as toxic as the other. Perhaps the first laboratory never looked to see if the rat testes were affected. This example stresses the fact that the statement "no effect from" is meaningless unless the effects searched for are enumerated, and unless some statement is made of the sensitivity of the methods for detecting an effect.

Other pertinent facts are important in judging the validity of conclusions from a study of chronic toxicity. Were enough control animals observed along with the treated animals so that statistical evaluation of differences, presumably due to treatment, was possible? Were the groups large enough so that small differences were statistically valid? What was the basic diet? Variations in diet may cause wide differences in results, even completely suppressing major symptoms of injury (*17*). How were the animals housed? There is little doubt that animals housed one in a cage develop fewer extraneous infections and in general thrive better than when several are in one cage. However, there is a series of articles showing that mated animals living *en famille* are more resistant to chemicals in the diet than are unmated animals (*1*).

One very important point in judging the importance to attach to a chronic toxicity report is the nature of the metabolism of the compound fed. It would be misleading to attempt to deduce the human toxicity of a material from the results of long-time experimental feeding, unless it is shown that the experimental species metabolizes the compound in the same way that it is metabolized in the human body. If such a similar metabolic path is not demonstrated, it is only prudent to use an inordinately large factor of safety to compensate for the uncertainty.

New Pesticides

The developer of a new pesticide will almost certainly not find the toxicology of the material outlined in the literature. The best he can hope for is to locate through *Chemical Abstracts* or *Biological Abstracts* information on a chemically similar compound. Inferences from data upon an analogous material may justify the cost of product development work, but they are of no value in proving safety of the use of a particular pesticide. In order to discharge his legal and ethical obligations, it will be necessary for the developer to have a toxicological study performed. The most widely accepted outline of what such a study should cover is that of Lehman and others (*13*); a similar outline is to be found in a National Research Council Food Protection Committee pamphlet (*7*). Both are primarily concerned with public health as regards residues of the pesticide in food, and neither gives sufficient attention to guarding the health of those who must apply the pesticide. They require lifetime feeding to one species, at multiple levels in the diet, usually defined as 2 years to the white rat, and at least 1 year to a nonrodent such as the dog or monkey. With the necessary biochemical study to settle questions of metabolism and storage in the body, this is expensive. However, the cost of toxicological experiment to protect the public health and to satisfy regulatory agencies is less than the cost of demonstrating effectiveness of a pesticide in greenhouse and field trials.

Maintenance of occupational health requires toxicological data referring primarily to inhalation, skin penetration, skin irritation, and sensitization. Occupational exposure is for the most part intermittent. In the manufacture of pesticides, where medical supervision can be provided, it is not unsound to rely for a time upon toxicological data on closely analogous materials, located through the abstract journals. In 1954 the American Conference of Governmental Industrial Hygienists began to include tentative values for the inhalation of dusts of pesticides in its annual threshold limits table (*2*), intended primarily to protect occupational health. The newest pesticides cannot be listed in this table, because it is based to a considerable extent upon industrial experience.

Pesticides in Use

Pesticides constitute a chemically heterogeneous group of materials. There is as yet no handbook outlining their toxicology, and if one should be prepared, current rapid developments would make it obsolete before it could be printed.

The most useful index of the periodical literature on pesticide toxicology is *Chemical Abstracts*. In 1950 the Federal Security Agency, now the U. S. Department of Health, Education and Welfare, held extensive hearings on "Tolerances for Poisonous or Deleterious Residues in or on Fresh Fruit and Vegetables." Some otherwise unpublished toxicological data were presented. The transcript of the hearings and the attached exhibits are not part of the open literature, nor are they arranged for easy reference, but they are available for scrutiny at the department in Washington. The *Federal Register* for October 20, 1954, published proposed tolerances based on the hearing. This contains hundreds of references to specific pages of the record and can serve as an index to lead one to the proper pages in instances where a trip to Washington is justified. The transcript of the hearings on chemicals in foods held by the so-called Delaney Committee (*5*) contains some unpublished data on the toxicology of pesticides.

Legal requirements for registration under the Federal Insecticide, Fungicide and Rodenticide Act of 1947 and for establishment of a tolerance under Section 408 of the Federal Food, Drug, and Cosmetic Act provide federal officials with adequate toxicity data before a new pesticide can be sold. It is unfortunately true that often these data are deemed to have served their purpose when registration and a tolerance have been granted. They do not necessarily enter the literature but remain "on file" with the Department of Agriculture and with the Food and Drug Administration. It is suspected that there are not sufficient journals to publish all the filed toxicological data on pesticides which may have a bearing upon public health.

Those not engaged in enforcing these acts are less well provided with toxicity data. A useful guide to the components of trade-marked mixtures is the "Pesticide Handbook," published annually (*9*). References to important toxicology papers on many pesticides are given in the Canadian "Guide to the Chemicals Used in Crop Protection" (*14*). Opinions without references appear in the "Official Publication of the Association of Economic Poison Control Officials" (*3*). A listing of information and opinion on a large number of pesticides can be found in the series of papers by Lehman (*12*).

There is a widespread belief that tolerances established under Sections 406 and 408 of the Food, Drug and Cosmetic Act are directly related to the toxicity of the respective pesticides, and that the layman can estimate relative toxicity by comparing tolerances. This is not true. The regulations establishing pesticide tolerances under Section 406 (*11*) make this clear, and recently Rankin (*15*) has emphasized the fact. Except for a few pesticides which have been exempted from the need for tolerances, no tolerance is set at a figure higher than the minimum amount required for protection of a crop against pests. Other ways in which the pesticide or related compounds may reach the food supply are considered, and the proportion of the diet represented by the particular crop is taken into account. When a numerical tolerance for a pesticide residue has been established under these principles it is almost always, but not necessarily, lower than the amount which is judged a safe level to be contained in the entire human diet. Relations between two tolerances ordinarily do not reflect the relative toxicity of the two pesticides concerned.

The primary concern for the toxicology of pesticides is for their effect on man under actual conditions of use, a most difficult field of study. Barnes (*4*) has made a survey of this subject with an extensive bibliography for the World Health Organization and Hayes (*10*) has briefly covered several pesticides. An epidemiological approach to the ideal is that of Fowler (*8*). This survey covered an area in the Mississippi Delta and considered various statistics of morbidity and mortality for urban and rural areas before and after the large scale application of modern insecticides began. Interestingly, there was found a general improvement in health conditions in the Mississippi Delta as well as in the entire state, and no evidence was found that pesticides were the direct or indirect cause of any chronic disease, nor a contributing cause in diseases generally recognized as having other etiologies.

There remain physicians who must treat persons receiving excessive amounts of pesticides. Happily, labels of all packages must state the identity of the active ingredients, and the antidotes or emergency treatments for highly toxic formulations. The trade name seldom delays access to toxicity information. But except for atropine in the case of the cholinesterase inhibitors, specific antidotes seldom exist for large doses of pesticides that have been swallowed and treatment for poisoning is, in the main, symptomatic. There is no place to send these physicians but to their own medical literature with the *Quarterly Cumulative Index* as the key to locating articles. Some help is available from Von Oettingen (*16*) and such reference books as De Sanctis and Varga's (*6*).

The state of the literature on pesticidal toxicology would be better if all the pertinent data now on file were to be published, and if some dedicated patient worker were to collect, evaluate, and summarize what has already been published.

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