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APPENDIX 1

Characteristics of Herbicides Used in Southeast Asia

The chemicals present in the defoliant mixes employed by the United States Air Force in Southeast Asia were developed originally to control weeds, that is, plants growing in places where man does not want them to be. Weeds present serious problems to agriculture because they compete with crops for available sunlight, moisture, and nutrients. For millenia the only weapons farmers had to use against weeds were mechanical, such as the hoe and the plow. In 1896 the modern use of chemicals to control weeds began with the work of a French scientist named Bonnet. He observed that the seedlings of wild mustard, a common weed in Western Europe, died when sprayed with a fungicide developed for use on grape vines. Bonnet later found that copper sulfate, a component of the fungicide, would selectively kill the wild mustard growing in a cereal crop. Other research showed that chemical compounds such as sodium nitrate, ferrous sulfate, and dilute sulfuric acid also acted as selective herbicides against broad-leafed weeds in fields of cereal plants with narrow, upright leaves. These compounds were dessicants and worked by extracting water from plant tissues. Their selectivity depended on the broad, level surfaces of the weeds collecting more of the chemical spray or dust than cereal leaves. The performance of these chemicals, except for dilute sulfuric acid, was, however, erratic.

Synthetic plant hormones or plant growth regulators, precursors of the primary herbicides used in Vietnam, were discovered in the 1930s. The first synthetic plant hormone herbicides were quite expensive and

therefore impractical as agricultural chemicals. A search undertaken to find less expensive and more active artificial plant hormones in 1942 identified 2,4-dichlorophenoxyacetic acid (2,4-D) as one of the most promising. Field trials during the World War II years proved that a related compound, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) could also be used as a selective herbicide. These two compounds later became important agricultural chemicals, and they were the primary components of several of the herbicides employed in the Ranch Hand program.( )

( ) Geoffrey W. Blackman, The Effects of Herbicides in South Vietnam, Part B, Working Papers: An Historical Survey of the Development of Herbicides (Washington. D.C.: National Academy of Sciences, February 1974).

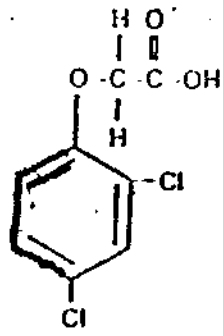
Three terms used throughout this study need to be defined: "herbicide," "defoliant," and "dessicant." A herbicide is a chemical which will kill or injure a plant when applied to air, soil, water, or the plant itself. The defining characteristic of defoliants is that they cause the leaves of a plant to fall prematurely, although the plant may or may not die as a result. A dessicant is a drying agent which causes a plant's tissues to lose their moisture, thereby killing or damaging the plant. The use of a dessicant may or may not result in subsequent defoliation. Thus, a given chemical may fall into one or more of these categories. Two of the terms, "herbicide" and "defoliant" are used practically interchangeably in discussions about the Ranch Hand program, but sometimes the differences in meaning may be important.( )

( )
Rprt, Review and Evaluation of ARPA "Defoliation" Program in South Vietnam [1962], p 5.

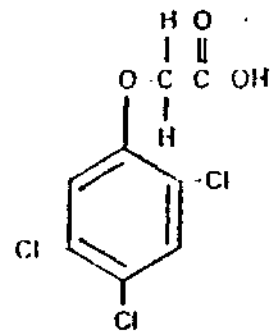
None of the herbicides used in Southeast Asia were of a new or experimental nature. They had all been used for several years in commercial agriculture both in the United States and in other countries. By way of illustration, in 1961, the year before the Ranch Hand program began, about 40 million acres plus hundreds of thousands of miles of roadsides, railroads, and utility rights of way were treated with phenoxy herbicides in the United States. Of this total, more than ten million acres, an area about one-fourth the size of South Vietnam, received aerial spray applications. The herbicides used in Southeast Asia were familiar agricultural chemicals, and aerial spraying of them was common.( )

( )
Rprt, Review and Evaluation of ARPA "Defoliation" Program in South Vietnam [1962], p ii.

2,4-D



2,4,5-T

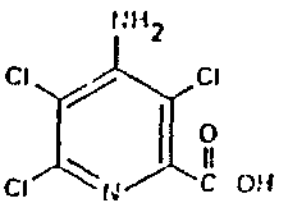


The compounds 2,4-D and 2,4,5-T are chlorinated phenoxy acids, and herbicides contain them in the acid form, as salts, and as esters. Which form is chosen for a specific application depends on desired characteristics such as solubility, volatility, and melting point. The persistence of 2,4-D and 2,4,5-T in soil is limited to only a few weeks, and high dosages are necessary to produce ~~the only known overt effect, viz. chlorane, on humans.~~ is chlorane any overt effects, of which the only positive known effect is Chloracne. However, considerable concern has developed over the potential danger from 2,3,7,8-tetrachlorodibenzo-para-dioxin, commonly known as dioxin, an impurity present in 2,4,5-T.

Phenoxy herbicides are growth regulators which have extensive effects on the structure of plants. Their action is generally rapid, and the fact that they may spread throughout a plant allows them to affect almost all of its biological activities. A plant's reaction to 2,4-D or 2,4,5-T may result in an abnormal production of buds or roots and the excessive growth of tissues. In lesser concentrations, the growth in tissues surrounding a plant's vascular system and the resultant restriction in the flow of nutrients may cause a slow death of the plant. In short, these two herbicides stimulate a ~~cancer-like~~ proliferation of tissues, ~~which causes plants to grow themselves to death.~~ ( ) ( )

( ) The Committee on the Effects of Herbicides in Vietnam, National Research Council, The Effects of Herbicides in South Vietnam: Part A, (Washington, D.C.: National Academy of Sciences, 1974), pp. II-21, 31; Floyd M. Ashton and Alden S. Crafts, Mode of Action of Herbicides, (New York: John Wiley & Sons, 1973), pp. 266-288.

Picloram

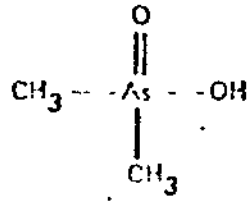


A third compound used in the Bush Kind herbicide formulations

was picloram. Sold commercially as Tordon, it has the formal chemical name of 4-amino-3,5,6-trichloropicolinic acid. In its pure state, it is a white powder with a smell like chlorine. Picloram's toxicity to man is thought to be lower than that of 2,4-D or 2,4,5-T. Like the phenoxy herbicides, picloram regulates plant growth, but the precise mechanisms involved are not known. It is an extremely mobile compound, being readily absorbed by both the leaves and roots and transported throughout the plant's tissues. Its mobility enhances its effectiveness against woody plants. Some of the effects of picloram are to stunt leaves and cause terminal growth to stop. Also, tissues along the stem proliferate, and the stem tends to bend and split. Roots may deteriorate, and the plant soon dies. Compared to 2,4-D, picloram is much more mobile, better able to penetrate roots, and more toxic to plants. One important difference between picloram and the phenoxy herbicides is that it is persistent in soils whereas the phenoxy compounds generally are not. Its persistence allows it to be used as a general soil sterilant under some conditions.( )

( ) The Committee on the Effects of Herbicides in Vietnam, The Effects of Herbicides in South Vietnam: Part A, p. II-15; Ashton and Crafts, pp. 413-418.

Cacodylic Acid



Cacodylic acid, formally known as hydroxydimethylarsine oxide and sold as Phytar, is not a plant growth regulator like the other three herbicides. Rather, it functions as an "uncoupler," keeping the plant from using the products of its metabolism for growth and tissue maintenance. It is thought that the effectiveness of cacodylic acid, like other arsenic compounds used as herbicides, derives from its ability to substitute arsenic for phosphorus in biochemical reactions. Its effects on a plant are to stop growth, attack membrane integrity, and cause drying, yellowing, and, eventually, death. Because drying is its primary observable effect, cacodylic acid is often labeled as a dessicant. It is a contact herbicide and is rapidly rendered ineffective in soil. Cacodylic acid, an organic compound, can replace inorganic forms of arsenic such as sodium arsenite and sodium arsenate in a herbicide role. These inorganic arsenic compounds are very toxic to both man and animals and can cause accidental fatalities. However, the ~~Cacodylic~~ acid itself is slightly toxic to humans, with a probable lethal oral dose of one ounce or more, although it has little or no toxicity when applied to the skin.( )

( ) Ashton and Crafts, pp. 147-160.

Combinations of these four herbicides were used to formulate the different color-coded agents used in the Ranch Hand operation in Southeast Asia. Table 1 lists the composition of these mixtures.

TABLE 1*

Major Herbicide Mixtures Used in Vietnam

Military Color Code or Trade Name[a]	Composition (active ingredients)
Pink	60% n-butyl ester of 2,4,5-T 40% isobutyl ester of 2,4,5-T
Green	100% n-butyl ester of 2,4,5-T
Pink-Green mixture	80% n-butyl ester of 2,4,5-T 20% isobutyl ester of 2,4,5-T
Dinoxol	50% butyoxyethanol ester of 2,4-D 50% butyoxyethanol ester of 2,4,5-T
Trinoxol	100% butyoxyethanol ester of 2,4,5-T
Purple	50% n-butyl ester of 2,4-D 30% n-butyl ester of 2,4,5-T 20% isobutyl ester of 2,4,5-T
Blue	100% sodium salt of cacodylic acid
Orange	50% n-butyl ester of 2,4-D 50% n-butyl ester of 2,4,5-T
Orange II	50% n-butyl ester of 2,4-D 50% isooctyl ester of 2,4,5-T
White	80% triisopropanolamine salt of 2,4-D 20% triisopropanolamine salt of picloram

a. Herbicide drums were identified by a four-inch-wide circular band of paint colored in correspondence with these color codes.

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* The Committee on the Effects of Herbicides in Vietnam, National Research Council, The Effects of Herbicides in South Vietnam: Part A (Washington, D.C.: National Academy of Sciences, 1974), p II-4; rprt, Review and Evaluation of AWPA "Defoliation" Program in South Vietnam [1962], pp 31-32; rprt, Capt Alvin L. Young, et al, USAF Occupational and Environmental Health Laboratory, The Toxicology, Environmental Fate, and Human Risk of Herbicide Orange and Its Associated Dioxin, Oct 78, p I-7.