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THE PRESENT STATUS OF CHEMICAL CONTROL OF
VEGETATION IN RELATION TO MILITARY NEEDS

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Institute for Defense Analyses

Research and Engineering Support Division

December 1962

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TECHNICAL NOTE 62-68

THE PRESENT STATUS OF CHEMICAL CONTROL OF
VEGETATION IN RELATION TO MILITARY NEEDS

December 1962

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RESEARCH AND ENGINEERING SUPPORT DIVISION

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Note 62-68

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INTRODUCTION

Under Project AGILE, a subtask was undertaken to provide "technical advice on the state-of-the-art in the United States, both governmental and non-governmental," on chemical means for controlling vegetation. The problem was broken down into the following categories:

1. Commercially available agents which could be applied in military operations within six months.
2. Chemicals in commercial production or laboratory development which could be brought to the operational status within 18 months.
3. Fundamental studies on plant physiology relevant to these short and intermediate range problems.
4. Botanical studies in relation to the task.
5. The proper function and distribution of intramural effort at Fort Detrick in relation to these objectives.
6. Relevancy of non-military government efforts to the problem.
7. Liaison, proprietary rights, and contractual arrangements in facilitating this program.

RECOMMENDATIONS

1. Short-range Problem

a. The evaluation of commercially available agricultural chemicals along the lines of herbicide-herbicide, herbicide-defoliant, herbicide-desiccant mixtures has the greatest promise for developing operational agents in the next six months.

Formulations must be investigated as a key part of these evaluations. The particular choice of agents can probably be best made by Fort Detrick with the USDA in consultation with representatives from industry, or by the panel discussed below.

b. The initial evaluations can be best conducted in industrial laboratories, second choices are the USDA facilities and Fort Detrick.

c. The field evaluation for tropical areas preliminary to operational testing can be carried out immediately at the facilities available to several of the larger companies. A good second choice is the Puerto Rican Commonwealth Agricultural Station. Independent USDA supervised facilities would have to be set up and manned; Fort Detrick supervised sites could be used if the others were unavailable.

2. Intermediate-range Solution

a. Industrial laboratories are the best source of candidate chemicals for phytotoxic evaluation. This should be implemented through 8 to 12 modest (\$100,000) synthesis and screening contracts. The contractor should be given maximum latitude in pursuing the program; primary and secondary screening should be their responsibility.

c. Closer interaction is required between those responsible for designing delivery equipment and those preparing the chemical agent regardless of their Service.

d. Fort Detrick should utilize a wide range of consultants from industry, the universities, research foundations, and the federal, state, and commonwealth agricultural stations, representing divergent points of view.

4. Advisory Panel

An advisory panel on the anti-vegetative program could play a critical role in meeting the present difficulties and laying out an effective plan for the future. In addition to the required statutory representation, it should include both military and civilian representation from the Air Force and Navy. It would be desirable to have a representative of the Office of the Assistant Secretary of the Army for R&D and the Office of the Chief of Research and Development, Department of the Army also represented. The panel should freely utilize consultants as suggested in Paragraph 3 (d) above.

5. Systematic Botany

An immediate effort should be made to compile a botanical register, from a qualitative and quantitative point of view, for Southeast Asia. A corresponding effort should be started for other potential trouble spots.

6. Phytotoxic Susceptibility

The relationship between phytotoxic susceptibility and phylogenetic strain should be studied.

7. Program Management

It would be an intrusion of an unnecessary administrative layer to have some institution such as Stanford Research Institute or Armour undertake a supervisory function in the expanding anti-vegetation program. The supervision of the anti-vegetation program as it applies to the military rightly belongs to Fort Detrick.

DISCUSSION

The consensus in and out of government, with which we concur, is that the Crops Division of the U.S. Army Biological Laboratory at Fort Detrick has responded splendidly to the present operational military requirements. In view of their history of budgetary caprice, intramural resistance, and lack of support by the military command, a far less effective response could have been expected. Now that the anti-vegetation program at Fort Detrick is being re-funded, it is appropriate to review the functions of the expanded staff in terms of the short and longer range objectives. Conclusions based on discussions with government and industrial contacts on the proper function of Fort Detrick are presented below.

It was made evident by our industrial contacts that rapport with the anti-vegetative program varied from satisfactory to antagonistic. Most companies appeared to be confused as to objectives and it was evident that the relationship was reciprocally unresponsive. Since no satisfactory utilization of the industrial capability can be made without improved rapport, this problem also will be discussed. Unlike many other technical fields, in which the principal expertise and competence lies in the military, the development of new anti-vegetation chemicals is fundamentally an activity of the commercial chemical industry. The military applications are peripheral to, and derivative of, the industrial competence. Industry must be utilized to a much greater extent if a more effective anti-vegetation program is to be developed.

From a botanical point of view, the above problem includes various aquatic plants, mangrove, and a wide range of grasses, ferns, palms, palmettos, trees, and herbaceous plants throughout South Vietnam. Although time did not permit an exhaustive search, conversations with a number of knowledgeable individuals make it appear unlikely that there exists an adequate botanical collation of this area from either the qualitative or quantitative point of view.

Our information indicates that mangrove is controllable. However, there is a paucity of information on the relative susceptibility of the various other species to herbicides. It is known that:

1. There are no rain forests in the area of military interest.
2. The upland area has a dry season in the winter in which there is less than one inch of rain. The tree species there are largely non-deciduous broadleaves.
3. In the virgin forest, the principal obstruction to vision requiring defoliation is the broadleaf evergreens which grow up to a height of 100 feet. The ground has relatively little cover.
4. There is a tropical scrub growth consisting largely of such flora as broadleaf evergreens which are often mingled with bamboo (running up to 40 feet in height) and imperata grass. This tropical scrub appears to be typical of those areas in which civilization has intruded.

The above categories do not clarify fully the tactical objective of the military defoliation program. The chemicals now in operational

trials, as of November 1962, are effective against all of the categories described above to a greater or lesser extent. The tactical problem to which research must be directed is the development of agents which attack a broader range of botanical species more rapidly. The agents must be applicable by air or ground spray devices. They should be non-toxic to the troops using it, to the natives in or passing through the area treated, and harmless to their livestock. Certainly, acute effects must be guarded against and the likelihood of chronic effect minimized. Since any agent will, in most areas, be used once, or at most a few times, it is not necessary to conform to the high safety standards required by the Food and Drug Administration for commercial agriculture. It is important also to guard against cosmetic effects, however transient, because of the propaganda value.

There appears to be a difference between the military and commercial terminology. The term "defoliant" appears to be used by the military to mean an agent which causes the leaves to drop whether it kills the plant or not. In commercial terminology an agent which kills a plant is a herbicide, whereas "defoliants" are exclusively non-herbicide agents which cause the leaves to drop from a commercial crop plant in order to facilitate harvesting. Desiccant appears to have the same meaning for the military and industry; namely, "an agent which causes the dehydration of leaves and their withering but not necessarily causing them to drop from the plant. Another category of agent, the soil sterilant is recognized commercially as an agent which prohibits the growth of all flora in an area whether temporarily or permanently.

There was some confusion among our industry contacts as to whether the military wanted, didn't want, or didn't care whether the agents offered were herbicidal or soil sterilizing. This needs clarification. In our understanding, sterilants have a definite place in roadside clearance whereas they might bring about erosion problems in the forest proper.

Several companies which bid on the two recently granted contracts had only a vague understanding as to what the military objectives are. This lack of clarity undoubtedly hampered some in the preparation of a satisfactory proposal. More specific information on the now classified aspects of military requirements would assist the bidders in submitting more responsive proposals.

II. Commercial Agents Immediately Applicable in the Field

The most promising source of new operational agents for use in the next six months lies in the combination of commercially available herbicides, defoliants, and/or desiccants. Formulation is the key to the successful field application of such agents.

The United States Department of Agriculture appears to be aware of the performance capabilities of all commercially available herbicides, defoliants, desiccants, and soil sterilants. They are familiar with the published literature as well as the results from the several state agencies. In addition, they have an extensive research program of their own. It is not clear that the able but overworked staff at Fort Detrick, since the arrest of their efforts in 1958 and its resumption

in 1961, have been able to apprise themselves of the performance capabilities of all marketed agents. It is ironic that the Fort Detrick anti-vegetation program was aborted in 1958 since this is approximately the time that a number of new agents representing different chemical types became available. The ready availability of the components of the agent used and the generally recognized range of effectiveness made it the logical first contender.

Our contacts in industry were unable to suggest any agent as promising as those being tested operationally for two reasons:

1. They had not been given the military requirements specifically in terms of the situation in Vietnam; and
2. They had no reliable, comprehensive, organized body of data on the effects of their chemicals in tropical environments.

We make no specific suggestions as to commercially available agents which should be investigated in the field. We do, however, recommend that mixtures of one or more different herbicides either with currently used agents or in various combinations, such as dinitrophenols and 2,4,5-T, should be tried. This type of combination should bring about rapid leaf drop and subsequent kill. One would expect that a defoliant (in the commercial sense) by itself would be of military interest only in certain tactical situations since growth in a few months would undo its short-term effect. A combination of defoliant and herbicide, however, presents problems which call for specific experimental work. One anticipates that if leaf-drop should occur too rapidly, the herbicide may not have time to be absorbed and bring about a subsequent

kill. Similarly, combinations of herbicides and desiccants also should be evaluated.

The third aspect of the utilization of current materials lies in formulation. The latter is the addition of additives, solvents, emulsifiers, etc., to basic agents in order to enhance their effectiveness. Effective formulation requires an individual with long experience and a knack bordering on art. This competence is best embodied in a few private consultants and some industrial laboratories.

It is our opinion that the recommendation of the commercial agents to be investigated can be best made by Fort Detrick and USDA at Beltsville in consultation with some of the larger corporations such as American Cyanamid, Dow, Monsanto, Shell, Amchem Products, and Giegy Chemical Corporation. We believe that the formulation and initial evaluation of these mixtures can be most rapidly, effectively, and economically accomplished through industrial contracts, whereas Fort Detrick's major contribution should be in large-scale field evaluation.

III. Industrial Chemicals at the Developmental Stage

In the intermediate and long-range efforts of the anti-vegetative program, the accumulated laboratory and screening data as well as the current developmental activities of the herbicide manufacturers could be profitably applied to the program.

In any technically oriented big business, such as agricultural chemicals, there is a build-up of unused technical information available only to company employees. In wartime, in the name of patriotism and national defense, the barriers of industrial security are lowered. In

a cold war, demands of proprietary self-interest are still dominant. In peacetime industry, by and large, is reluctant to give to the military proprietary information which has been accumulated at great expense. In the herbicide-defoliant field, a small company easily can accumulate data on 200 to 300 potential agricultural chemicals in a year. A large company can accumulate data on that many in a month. A vanishingly small percentage of the compounds initially screened for herbicide activity, because of unfavorable economics, toxicity, or an inappropriate spectrum of biological activity, is ever commercially developed. It still may be to the company's interest to keep the performance data on these unsuccessful compounds secret to avoid aiding its competitors.

The Food and Drug Administration requirements which must be met by agents that are to be applied to crops make the development of a crop chemical exceedingly expensive - ranging from \$250,000 to \$2,000,000. This expense is incurred largely in animal feeding studies, field evaluations, residue determinations, and investigations of the metabolic disposition of the chemical in the plant. Such expensive studies probably are not necessary for a military agent.

Several of the larger companies indicated that they did have, or might have, agents in their accumulated files which they would be willing to make available to the military if they were approached with a specific objective. It should be pointed out that the staffs of the state and federal agricultural agencies also are largely uninformed of the behavior of these test chemicals because of industrial security.

Chemicals under development present a delicate problem to industry. The revelation of performance characteristics might reduce a company's lead time over its competitors by several years. The opinion was expressed frequently that a specific military request, coupled with a better safeguard of the companies proprietary rights, would induce them to reveal data on promising compounds. An additional inducement would be to give the companies more responsibility than is presently the case for the screening and evaluation of their compounds.

IV. Fundamental Studies

There is a slow but accelerating production of fundamental studies on phytotoxic action. In spite of more than 15 years of investigation, there is no definitive account of the mode of action of 2,4-D, the oldest of the commercial organic herbicides. In contrast, there has been marked success in investigating the mode of action of several of the newer herbicides. Monuron, chlorophenyldimethylurea, has been shown by Todd and others to interfere with the Hill reaction in photosynthesis. Hilton of DuPont and others of Beltsville have shown that Dalapon, salts of 2,2-dichloropropionic acid, and other chloro-acids compete for pantoate in the enzyme involved in pantothenate synthesis. There also has been increasing activity in the study of absorption and translocation of phyto-active chemicals.

These basic advances are being made largely in the universities and the USDA facilities in the United States and by a group of workers in England.

Fundamental studies at present are largely irrelevant to the short and intermediate range problems. In the long pull, these studies present the greatest promise since they are the foundation upon which our understanding of phytotoxicity rests and this knowledge could be crucial in the selection of compounds to be studied in the future.

At one time, Fort Detrick was a center of fundamental studies. It is no more and, in our opinion, it should not be. Fundamental work is best conducted in an uninhibited environment of free exchange such as exists at the universities. In our opinion, therefore, the military should provide support for basic research. We believe, also, that Fort Detrick should be given the opportunity to take full advantage of this information by the appointment of consultants representing disparate points of view.

V. Proper Function of Fort Detrick in the Anti-Vegetative Program

As pointed out above, the military applications of defoliants are a relatively minor but specialized aspect of the general technology of plant chemistry. The military have specific problems peculiar to their needs, but the principal resources to solve them are located in industry. Fort Detrick should, therefore, play the primary role in formulating these unique problems and in developing the appropriate technology to solve them. To do this, they need a capability which ranges from basic research to applied technology. One of the key problems is to achieve the proper balance of these activities. The Fort Detrick operation should go into the fundamental aspects of plant chemistry only far enough to maintain a competence at the installation

which will enable it to interpret fundamental research reports from all sources. On the other hand, fundamental studies in plant chemistry are currently under-funded at the universities and the Department of Defense would do well to support this activity.

The second activity, that of evaluating new agents, can be divided into two parts - synthesis of new agents, and their screening. By the very nature of organic synthesis, small installations cannot have a full spectrum of synthetic capability. Fundamentally, industry and, to a lesser extent, the universities should be the source of new chemicals. The synthesis of these new compounds can be best done on a contract basis and these laboratories should be given wide latitude to investigate new chemical structures. However, Fort Detrick must have sufficient synthetic organic chemical capability to permit it to follow up promising synthetic leads where an in-house effort is desirable.

The other aspect of new agent evaluation is primary screening to select those chemicals which have the slightest promise of phytochemical activity. Whenever possible, screening should be the responsibility of the organization synthesizing the compounds in order to provide a high rate of feedback of the results to the synthetic program. In this way, interest in the research would be heightened and economies in both time and money affected.

Thirdly, the application of plant chemicals for military purposes should be the strong point of the Fort Detrick operation, i.e., problems connected with modes of delivery as well as operational evaluations, and

large-scale testing in those environments of military interest.

In summary, the use of phytochemically active agents is primarily a special facet of a much larger technology. Fort Detrick needs a full range of capability to stay abreast of developments but its emphasis should be overwhelmingly on those aspects which are peculiar to military applications.

VI. Other Government Efforts in Plant Chemistry

The principal focus of non-military federal government activity in phytotoxic agents is the United States Department of Agriculture; comparable agencies exist at the state levels. Their interests range from the improvement of agricultural yields without impairing the wholesomeness of food, control of undesirable plants in wooded lands to help the lumbering industry, control of growth along rights of way used for power transmission lines and transportation, to control of weeds in navigable waters and aquatic sports areas.

These agencies conduct extensive evaluation programs at the applied level which are designed primarily to measure the effectiveness of new agents in their various fields of interest. The state and federal agencies usually are given only those materials which the manufacturer has decided, on the basis of his own evaluations, have a good chance of being commercially successful. Thus, the governmental agencies' forte is the knowledge of the effectiveness of commercial chemicals being marketed or being offered for commercial development. Their weakness is a lack of information with respect to the far greater number of materials rejected by the manufacturer for commercialization.

For the current military needs, therefore, the agricultural stations, in particular the USDA, are in a key position to recommend to Fort Detrick those commercially available agents which should be brought immediately to operational evaluation.

On the level of secondary plot size screening, the U.S. Department of Agriculture and the state agricultural stations have conducted field evaluations for many years, especially in temperate zones. They do not have the manpower, which can be applied immediately to the short and intermediate range military problems.

Industry with its long experience in formulation must be utilized to the maximum. The proper function of Fort Detrick is to coordinate these two competences and to channel their efforts into a productive, efficient program. Particular attention should be given to the Puerto Rican Commonwealth Agricultural station which has a climate similar to that of Southeast Asia. The flora may not be comparable in their reactions to the phytotoxic agents.

The Forest Service is, in general, interested in removing undesirable trees from those areas which are commercially significant, for example, the selective killing of scrub oak in pine forests. Rapidity of response, a military necessity, has not been a Forest Service requirement. Secondly, their interest is directed toward selectivity or specificity of action. Thirdly, many of their tree-killing techniques such as frilling (prying a ring of wedges of bark away from the tree and applying the chemical to the wound) are militarily impractical.

In summary, due consideration and emphasis should be given to the various aspects of the development program. The prime responsibility for formulation and its associated screening should be assigned to industry, directly or indirectly. The facilities for plot-size screening are most frequently found in the state, commonwealth, and federal agricultural stations.

VII. Industrial Liaison

It became apparent early in our investigation that the principal focus of phytochemical technology lies in industry. The military has not been receiving full advantage of this technology because of a failure to communicate its unique problems, and industry's fear of losing its proprietary rights.

Economic Difficulties - Contact after contact in the industrial laboratories made the point that the agricultural chemical business is highly competitive. An awareness by the competition of the performance of a developmental chemical or even the general trend of new research, can mean large dollar losses. When data is submitted to the various government agencies, it is with the understanding that secrecy will be maintained on proprietary information. In a few regrettable instances, this confidence has been violated, causing the suppliers to become over-cautious. Most of our contacts agreed that the individuals to whom the information is given initially act in good faith. Two effects act to undercut their good intentions. One is a relatively rapid turnover

of personnel and the other appears to be a needlessly broad dissemination of information to those who have no real "need-to-know." Other difficulties are the failure to clarify and publicize industry's opportunity to retain commercial rights and concern that an agent might be classified "secret" thus preventing the development of a patent position.

In spite of these adverse reactions, the industrial representatives expressed a desire to serve the country, even at some risk to proprietary interest, provided:

1. The problems were made explicit preferably through face-to-face contact; and
2. There is an opportunity to earn a fair profit.

The salient features of the last point are the firm guarantee of commercial rights to any agent developed in a government program, and the opportunity to turn previous laboratory investigations to profit by developing military uses for agents which the company had previously rejected for commercialization. In this manner they will be able to retrieve some of their research expenditures.

Cost Sharing - In connection with the granting of two recent contracts by Fort Detrick which went to Penn Salt and Monsanto, respectively, a number of complaints were made with respect to cost sharing. In this arrangement, the contractor absorbs part of the program's cost presumably because his commercial interests are being aided by the contract. Cost sharing tends to be promoted by those who will gain the most through federal subsidy, whereas cost sharing tends to be discouraged or not engaged in by those who have the least to gain but the most to give to the federal effort. A company with no great

commitment in a field may undertake a great deal of cost sharing, thus providing for itself an opportunity to break into a new field. In effect, rather than subsidizing a federal effort, it is utilizing federal money to subsidize its own interests. In contrast to this, the large company with a tremendous backlog of information and technology, when asked to engage in cost sharing, is subsidizing the federal effort.

The industrial reaction to cost sharing, in most cases, was unfavorable. This attitude is based on the fear that in some cases purchase price may take precedence over quality of research.

Communication Problem - The failure to communicate adequately the military needs to industry has been a major factor in retarding response. We will discuss the problem in terms of (a) the Industrial Liaison Office which was organized officially to bring new chemicals into the military program, and (b) the handling of the two recent Fort Detrick contracts as specific examples of difficulties.

(a) Industrial Liaison Office - The general attitude toward the effectiveness of the Industrial Liaison Office varied all the way from "very favorable" to "ineffective." There is a tendency for those companies who are active participants or who have a long-standing history of involvement in military programs to consider the Industrial Liaison Office effective. Instances were reported where companies were recruited into the program by specific contacts with Dr. Metcalf, the Chairman. At the other extreme, the companies which had relatively few dealings with the military felt that the Industrial Liaison Office was not doing a good job. They tended to look upon the acquisition program as indiscriminate and ineffective.

With respect to the herbicides, the opinion generally expressed was that the significant manufacturers already had screened most of the compounds before they submitted them to the Industrial Liaison Office. They felt that the military should not be conducting a redundant effort in screening these chemicals but rather should be consulting more closely with the synthesizer with reference to the phyto-activity of the compounds. More important was the statement that the compounds submitted to the Industrial Liaison Office were "highly filtered." It was said that only those compounds which were either known to be of low activity or for which there had been established a firm patent position were submitted.

The most interesting criticism of all came from one company which has submitted the names of hundreds of compounds in the recent past and has received no request for evaluation samples. The conclusion drawn by this supplier was that not even the military is interested in the Industrial Liaison Office acquisition program.

A contrast to these criticisms relating to herbicides is the awareness by industry of military interest in highly toxic materials. Almost without exception, industry has cooperated by submitting samples of new compounds for tests where the preliminary data was suggestive.

(b) Negotiation of Contracts - Our industrial contacts showed spontaneous interest in discussing the various aspects of submitting proposals for an anti-vegetation research contract with Fort Detrick. While none of the remarks below could be said to represent the opinion of all the industrial companies, there was sufficient consensus to merit presentation.

The bidders' conference seems to have left some contractors confused on objectives. A request for bids for the synthesis of phosphorus, acetylenic and other compounds was made. Many interpreted the request to mean too heavy emphasis on the first two categories. Also, there was a great deal of criticism of the limited screening requested of the contractor. The latter was to screen the new compounds against one plant and Fort Detrick was to screen them against additional ones. One plant was not regarded as a singularly significant for diagnosis. Our contacts generally believed it was much more economical and efficient to permit the contractor to conduct the primary and possibly secondary screening.

We believe the contract work would be more efficient and effective were the contractor involved in goal planning, synthesis, formulation, primary and secondary screening, and field evaluations. Also, many of the large corporations and some of the smaller ones have tropical and subtropical evaluation facilities in operation or available to them which could respond almost immediately to the military requirements for secondary and field screening. Such a systems approach could be most effectively carried out in dealing with the larger companies such as Dow, Shell, DuPont, American Cyanamid, Monsanto, etc.

Some of the industrial contacts were sufficiently interested in the military program that they wished to initiate unsolicited contract proposals. Apparently the opportunity and the mechanism for doing this was not made clear to them at the bidders' meeting.

VIII. Manufacturing Capability to Respond to Military Requirements

An important question is the ability of the manufacturer to produce large quantities of a new chemical in response to military requirements. This problem has two important aspects - manufacturing facilities and the cost of the products.

For primary screening purposes, a few grams of material are quite adequate and are the scale on which a synthetic program is and should be conducted. Field or plot screening evaluation might call for one pound quantities. In almost all cases, it was felt by the manufacturers that they could respond to such a requirement within a month. Should an agent be successful at that time there probably would be a need for quantities in the range of 20 to 25 pounds for a large-scale field evaluation. The response time in this case probably would not exceed three months.

Application of a new agent at the operational level might involve synthesis of 50,000 to one million pounds per year. The larger manufacturers were, by and large, confident that such a need could be met provided fairly broad latitude in cost was allowed in order to cover the extra expenses inherent in the large-scale production of a new chemical.

It is our belief that in looking for this new military agent, one could justify, initially, several-fold higher costs than that allowable for an established commercial agent. We believe that if industry were explicitly informed that such an opportunity exists, it would be greatly stimulated in its search for new phytochemical agents.

IX. Botany

Our observations indicate that there is significant literature available on the botany of the Indo-Chinese peninsula. This is not well organized nor is it available conveniently in the English language. We believe that some taxonomic botany would be most helpful to those attempting to develop improved herbicides and defoliants. The objectives should be:

1. To gain a clear understanding of the relative military importance of the specific species;
2. To explore the relationships between chemical sensitivity and taxonomy in temperate and tropical regions.

Our preliminary investigations suggest that considerable pertinent information is scattered among the various companies which have plantations or commercial interests in the tropics: these are primarily the rubber, coffee, banana, and cocoa growers. A taxonomist with a chemical orientation undoubtedly could perform a useful service in collecting and codifying this information. Of particular note is Maurice Schmid, a Frenchman, whose English, we understand, is excellent and who is considered to be the outstanding authority on the botany of Vietnam.

APPENDIX

The following organizations and individuals have been contacted in our attempt to evaluate the current state of the art of vegetation control by means of chemicals:

1. Biology Department, Harvard University
Cambridge, Massachusetts
 - a. Dr. Duncan Clement
 - b. Dr. Kenneth Thimann
2. United Fruit Company
Boston, Massachusetts

Dr. N. C. Thornton
3. Colonel K. C. Emerson
Office of the Secretary of the Army(R&D), Pentagon
4. Smithsonian Institution
Washington, D. C.
 - a. Mr. Morton
 - b. Dr. F. A. McClure
5. Esso Research Center
Linden, New Jersey

Dr. H. H. Yowell
6. W. R. Grace & Company
Clarksville, Maryland

Dr. W. K. Loughlin, Director of Research
7. Fort Detrick
Fredericksburg, Maryland
 - a. Dr. Minerick
 - b. Dr. Brown
 - c. Dr. Darrow
 - d. Dr. Kingsolver

8. U. S. Department of Agriculture
Washington, D. C.
 - a. Forest Service, Dr. Donald Lynch
 - b. Agricultural Research Center
Dr. D. C. Haller
Assistant Director
 - c. Plant Industries Station, Beltsville, Maryland
 - (1) Dr. W. D. McClellan
 - (2) Dr. D. L. Klingman
 - (3) Dr. Shaw
9. American Cyanamid
Princeton, New Jersey
 - a. Dr. Frank Stark
 - b. Dr. John King
10. Stauffer Chemical Company, New York City
 - a. Dr. Chester Arnold
Vice President in Charge of Research
 - b. Dr. Donald Mastick,
Assistant to the Vice President
 - c. Dr. D. Dorman
Associate Director of Biological Laboratories
 - d. Mr. Obrecht
Research Director, Chemical Division
11. Boyce Thompson Institute
Yonkers, New York

Dr. George McNew, Research Director
12. Dupont Chemical Company
Wilmington, Delaware

Dr. Max Goebel, Director of Research
13. Texaco Research Center
Beacon, New York

Dr. C. L. W. Swanson
14. Pennsylvania State University
University Park, Pennsylvania

Dr. Donald Frear

15. National Geographic Society
Washington, D. C.
16. Ethyl Corporation
Detroit and Baton Rouge
 - a. Dr. Ellis Rifkin
 - b. Mr. J. D. Libby, Jr.
17. Shell Development
Emeryville and Modesto, California
 - a. Dr. R. G. Larsen,
Director of Agricultural Research
 - b. Dr. J. Van Overbeak
 - c. Other staff members
18. Standard Oil of California
Richmond, California
 - a. Dr. B. F. Quisenberry
 - b. Dr. I. Levine
 - c. Dr. L. R. Gardiner,
Director of Agricultural Research
 - d. Other staff members
19. University of California
Davis, California

Dr. A. S. Crafts
20. California State Department of Forestry
Sacramento, California

Dr. L. Burcham
21. Dow Chemical
Midland, Michigan
 - a. Dr. W. P. Schambra, Defense Liaison and Planning
 - b. Dr. K. C. Barrons, Plant Scientist
 - c. Dr. L. C. Chamberlain, Assistant to the
Director of Research
22. Chemagro
Kansas City, Kansas

Dr. vonRumker

Monsanto

NAME & LOCATION C. H. Russell - St. Louis, Missouri

July 16, 1970

Mr. A. E. Leisy - Krummrich
Mr. M. L. Haulard

n-T Butyl Ester

TO : Mr. R. E. Baynard

You will recall that 28,560 pounds of the Tech. T Butyl Ester shipped to Imperial Chemical, Shanandoah, Iowa, against order number 605150 was returned. This material is stored at Mid-American warehouse and except for containing 50 ppm iron, is good ester. This ester was some of the material we were using in Orange Band.

The Krummrich Plant has, on a special form, asked "should this material be discarded?" If the ester is emulsified and cut to 4#/gal. with solvent, a jell will occur on long storage, however if it is formulated and applied immediately, there should be no difficulty. Also, if one part of this is diluted with 5 parts low iron ester, the iron content will have been diluted to below 10 ppm and jelling will not occur in the 4# formulation. So rather than discard it, I should think you can sell it at some discount to some formulator telling him the above. What about Farmland, Chipman, Thompson Chemical here in St. Louis or at the worst, give it to someone who can use it if they'll pay the freight. Otherwise the product will apparently end up on the Krummrich toxic dump.


C. H. Russell

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CONFIDENTIAL

SUBJECT TO PROTECTIVE ORDER.

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production, and human and animal toxicities for most of these candidate chemicals were unknown, and any one of these factors could have limited or delayed active help to Vietnam. In any case, it is extremely doubtful that anyone could have been convinced of the real worth of a chemical as a result of testing only a few grams or even a few gallons. With these limited quantities, only a small number of the array of unknown species of vegetation could have been tested. It is not intended in any way to minimize the importance of such testing, but rather to put it in perspective in relation to the combined "research - aid to Vietnam" objectives. Thus, these candidates were tested in the latter part of December and in January, whereas the major aerial testing of the 2,4-D and 2,4,5-T chemicals was conducted from August to October. The chronology of tests, equipment, chemicals, and observation dates are listed in Section VII of the Supplement.

Actual figures on viscosities were not available until 17 April 1962 because the necessary equipment was not at hand. Table II shows both absolute and relative viscosities for the purple, pink, and pink-green chemicals.

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TABLE II. VISCOSITIES OF CHEMICALS COMPARED WITH WATER^{a/}

Temperature °C °F		Water	Purple	Pink	Pink-Green ^{b/}
Absolute Viscosity, centipoises					
38	100.4	0.6814	590.5	1028	1319
32	89.6	0.7679	1115	2076	2650
28	82.4	0.8360	1688	3450	4270
23	73.4	0.9354	2981	6522	7562
19	66.2	1.0299	4768	11370	12930
14	57.2	1.1709	8441	22494	30160
Viscosity Relative to Water					
38	100.4		853.7	1508	1934
32	89.6		1452	2703	3451
28	82.4		2091	4126	5108
23	73.4		3187	6972	8084
19	66.2		4830	11340	12550
14	57.2		7209	19210	25760

a. Prepared by Ralph E. Buschmann.

b. 1:1 mixture by volume.

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III. EQUIPMENT

A. VARIATIONS

Inherent differences in various aerial vehicles for delivering sprays affect the deposition of the spray. Helicopter rotors provide a downward blast on the spray that can cause a desirable spray turbulence within a forest canopy, depending on the height above the trees from which the spray release is made. Section VIII of the Supplement describes the effect of spraying forests from a helicopter.

Releases from fixed-wing aircraft are in the main dependant on settling of the spray. The turbulence created by the propellers causes the spray from each boom to spiral out behind the aircraft to give the impression, under otherwise quiescent conditions, of two horizontal cylindrical clouds floating in the air. However, if conditions are not quiescent and an inversion does not exist, the spiraling effect from the propellers seems to aid in the upward dispersion of the spray; the fine particles so impelled have little tendency to settle but are dissipated, aimability is thereby lost, and desired deposition rates are not achieved.

The H-34, C-47, and C-123's all had split booms; that is, essentially two separate booms are operated, one on each side of the fuselage. Thus, at very low altitudes the two cylinders of spray may enter the foliage before coalescing, leaving unsprayed foliage, under the fuselage. At higher release altitudes the sprays have an opportunity to coalesce and even out the spray deposit if the conditions for settling are present.

To my best knowledge, planned flow rates, altitudes, and airspeeds for various swath widths were made to match the deposition rates desired. Thus, the amount of chemical deposited was limited and the evenness and rate of deposition were dependent on factors discussed above. Within a given swath (and especially with a crosswind release) the spray will deposit with the larger particles impacting first and the finer particles being carried farther downwind. Obviously, at some point downwind the quantity of chemical deposited tapers off and the amount becomes sublethal.

It is customary in spray work to use area as a parameter, which usually does not take into account the leaf surface of vegetation contained in that area. There can be considerable variation in the area of leaves contained on a given unit of land, depending on whether the vegetation is grass, corn, or jungle. There is no quick, easy, or exact method of allowing for total leaf surface. The rates of deposition sought in these tests and the flow rates calculated to provide them were, therefore, quite arbitrary but were guided by results achieved spraying about four square miles of forest at Camp Drum, New York, in 1959 (See Section VI of the Supplement for details.)

B. INSTALLATION AND OPERATION

1. C-47 Spray Equipment

a. Description

The equipment installed and used in a VN C-47 aircraft had been used for several years by a USAF Insect Control Group at Langley Air Force Base. The tank had a capacity of 675 gallons and was formerly used in a B-26 as a bomb-bay fuel tank for increasing range. The tank size is approximately 3 feet by 3 feet by 11 feet. A 3-inch filler pipe and vent pipe extends upward and to the outside of the fuselage.

Connected to the rear of the tank is a Marlow self-priming centrifugal pump (Model 2B2, 200-gpm output) driven by an air-cooled 5-hp Wisconsin engine. A 2-inch discharge line runs from the pump to a T connection. One line from the T runs through a valve and hence into the tank. The other line runs through a valve to the outside of the fuselage at the bottom of the aircraft and hence to a Y to connect to the left and right booms. The two valves are actuated by remote control from the cockpit. When one valve closes the other opens simultaneously. The pressure from the pump can be regulated only by pump and engine speed. No pressure regulator is incorporated into the system. The pump engine is started and the speed set manually. A quick-dump valve is incorporated as a safety feature.

The left and right booms are 1½-inch (outside diameter) pipe and each has an effective length of 12½ feet. They are mounted on wing braces and extend 22 inches below the lower wing surface. The two inboard ends of the booms are 36 feet apart. Each boom has outlets for 22 nozzles, a total of 44.

The nozzles used were Spraying Systems B-10 Whirljet nozzles with diaphragm check valves. The orifice is 3/16 inch in diameter and forms a hollow cone pattern of 72 degrees when operated in a static spray test at 20 psi (1.7 gpm with water).

Some minor difficulties were encountered during the installation of the equipment. The C-47 the VN were using was an older model than the US C-47 from which the spray equipment had been removed. Some changes were necessary in the wiring between the pilot's control panel and the spray-valve actuating mechanism. Other changes in fittings were insignificant.

b. Tests

Because of the urgency of the situation in Vietnam there was not time to conduct tests in the US with the C-47 and the liquid chemicals to be sprayed. Tests to determine particle mass median diameter (MMD), flow rate, and per cent recovery (mass deposit) of the chemical to be used in VN would have been highly desirable. Estimated dosage rates of the chemicals to kill large trees of unknown species are about five to ten pounds per acre.

Previous tests with similar spray equipment and chemicals in the US have had as their objective a small particle diameter and uniform large-area coverage at deposit rates of one pound per acre and less. This application rate is sufficient to kill many economic food and fiber crops.

Some spray deposit tests were conducted during April 1953 at Beltsville Maryland with the C-47 and the spray equipment described above. The liquid spray material was DDT and fuel oil, which is much less viscous than the solutions used in VN. The recovery ranged from 59 to 86 per cent for the six test runs conducted. The highest recovery was obtained from the test conducted under good inversion conditions. The MMD of the particles was 165 microns.

The C-47 spray equipment did not give the desired or anticipated effect at Chon Thanh (Test 2). Several factors are responsible: the pumping system failed to provide the pressure required for the desired flow rate. The amount of pressure drop in the lines from the pump to the nozzles is not known. The pressure at the pump registered 30 psi (the maximum) but at the discharge nozzles it may have been considerably less.

c. Operational Difficulties

Considerable delay was encountered in getting to the test site on the ground because of late arrival of equipment and of security clearance to work in the area. Thus, the spray run was not started until 1030 hours, when the meteorological conditions were neutral or lapse. Hence, most of the smaller droplets may have drifted off the target. The wind direction angled off the target by 10 degrees, and red indicator cards showed considerable drift of the spray off the intended target.

2. 14B Spray Tank

The 14B was designed to carry chemical or biological material externally on light piston- or jet-engined aircraft.

Two 14B tanks arrived in Saigon from Iwo Kuni, Japan, on 1 August 1961. The two units had apparently been in storage for some time. They were corroded, wires were misplaced or missing, and a few parts malfunctioned. USMC Sgt. McIntosh displayed much ingenuity in his efforts to get the units functional. By rewiring, interchanging, and repair of parts one unit was made operational.

Each unit has three major components: the nose section containing the high-pressure compressed air tank and control assembly; the center section containing the liquid reservoir (90-gallon capacity); and the tail section containing the discharge valve and control assembly.

Operation of the units is controlled from the pilot's control panel in the cockpit. Three different flow rates can be selected during flight. However, for a flow rate other than those present, the central microswitch in the tail assembly can be adjusted and reset for any of several flow rates.

When the unit is functioned, air is fed from the air tank into the center section (liquid reservoir) at 100 psi and liquid and air are then directed out and around the spear valve and diffusion cone into the airstream.

The unit was mounted on a VN AD6 aircraft and functioned perfectly. Particle MMD is estimated to have been about 290 microns.. Previous tests with the 148 revealed an MMD of 272 microns at 180 knots airspeed, 173 microns at 360 knots, and 107 microns at 550 knots.

3. H-34 and HIDAL Spray Equipment

This equipment was designed and fabricated by the US Navy for use on rotor-winged aircraft to spray insecticides. It consists of a 200-gallon cylindrical tank located in the cabin. A 25-gpm electric pump, located at the bottom of the tank, transfers the liquid from the tank to the booms, which extend about 25 feet out and slightly to the rear of the fuselage in a delta design.

Each boom was equipped with 21 Spraying Systems T-jet nozzles. Each nozzle had an orifice diameter of 0.062 inch and delivered 0.6 gpm of water at 40 psi pump pressure.

Some malfunctions were encountered during the installation and operation of the equipment. A leak developed at the bottom of the tank at the outlet to the pump. A brass elbow threaded into a nylon or plastic plate did not provide a substantial seal. The plate was replaced with one made of brass. The carbon vanes in the rotary vane pump broke after a short time. They were replaced with vanes fabricated of nylon. The upper forward boom brace mounting cracked the fuselage of the aircraft and the HIDAL system was grounded for several months. A bracing cable was installed in late December to connect the left mount with the right mount inside the fuselage.

4. Buffalo Turbine Sprayer

This is a ground-operated spray rig that can be towed behind a vehicle or mounted in the bed of a pick-up or larger truck.

A 36-hp Wisconsin engine drives the turbine and the nylon roller-type pump. The turbine delivers up to 14,000 cfm, the pump capacity is one half to 30 gallons per minute at pressures up to 150 psi. A stainless steel tank (100-gallon capacity) is used for the liquid reservoir.

In operation the liquid is pumped from the tank through a pressure-relief valve and into the small boom containing four liquid nozzles. The boom and nozzles are located inside a fishtail air nozzle attached to the exhaust end of the air turbine. The high-velocity air stream breaks up the liquid and carries the particles some distance away.

The particle MMD is said to be 75 to 80 microns. Although the particles are much smaller than those from aerial releases, the effect of meteorological conditions on deposition is much less. The particles are released at ground level and are impacted on the foliage rather than being wholly dependent on inversion conditions for sedimentation.

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IV. TESTS

A. PERFORMANCE STANDARDS

From 10 August to the end of 1961 all chemical tests in which the materials were released from aircraft were performed with chemicals of the 2,4-D or 2,4,5-T type. These are well-known plant growth regulators or vegetation control chemicals that have gained wide recognition and use in the United States for killing vegetation.

A very important point is that, no matter what chemicals were to be tested, they were to be tested as soon as possible, with the possibility of being used on a wide scale to aid Vietnam. Therefore, a host of other factors had to be satisfied as well; otherwise, any one of the following factors could have prevented their use. Some of the more obvious factors were availability, cost, and safety to humans under conditions of spray and handling.

Ratings in these tests were recorded by adjectives and/or estimated percentages of effect as the situation allowed, bearing in mind the following factors:

(a) Is the evidence sufficient to indicate that the chemical has in fact been reasonably well deposited on the vegetation? Better effect can be achieved on a susceptible tree if all its leaves receive a few drops of chemical as opposed to only one side or only the very top of the tree receiving all the chemical. In this connection, forms of the chemical known as volatile esters were requested subsequently in order to achieve more uniform coverage within a forest canopy.

(b) Is the vegetation in a stage of growth capable of responding? Actively growing (not dormant) vegetation responds more quickly and thoroughly to these chemicals, whereas dormant plants can usually respond only when they re-enter a state of active growth.

(c) Are the species encountered (although unknown) susceptible to the chemical? Even the Soviets are having difficulty with the unknown species in North Vietnam, and they are free to roam the country (see reference JPRS: 11373 dated 29 November 1961) as indicated by the following excerpt. The title of this paper is "Soviet Botanists in Vietnam" by A. L. Takhtadze.

"As we had already known, in the democratic republic of Vietnam there are yet no botanical institutions capable of organizing or coordinating this study of the plant world of the country. Botanical research is performed mainly by the chairs of various colleges and universities; however, with the exception of a textbook on the Taxonomy written by the head of the Department of Botany of the Pedagogical Institute, La Kha Ke, unfortunately there are no reference books in Vietnamese on botany in general or on the vegetable

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kingdom of Vietnam in particular. There is no good herbarium either. Therefore, identification of plants in Vietnam presents great difficulties, and as a result, many important trees providing valuable wood, and also a relatively large number of medicinal plants have not been accurately identified until the present time."

(Additionally, the writer took a special trip to Singapore from September 28 to October 3 in order to consult with Dr. Abbe, a visiting professor from the University of Minnesota who was in Southeast Asia on a Fulbright Grant. He had, he told me, a team of three collecting forest species in South Vietnam and in six months' time this team made 14,000 collections. He estimated perhaps 50 of these collections could be identified as to genus only. The rest of the collection, he indicated, would take several years to identify and all of his samples were dried, dead material not capable of the vegetative propagation that would be needed in order to test chemicals. Neither did he have a supply of seed for these various species.)

(d) Has sufficient time elapsed after spraying for the responses to occur? The length of time may vary from two to six or eight weeks for woody vegetation, depending on its state of growth, inherent susceptibility, etc. A given plant may, in fact, be dead (incapable of regrowth) for some time before it is really obvious and vice versa, that is, it may appear to be dead and resprout.

(e) And (in Vietnam) was it possible to make observations of the kind necessary to evaluate fully the chemical effects? South Vietnam is actually engaged in a shooting, bloody war; therefore, any movement within the country of personnel who are there to help them, though noncombatant, are governed by very stringent regulations. Included in these regulations is a rule that Intelligence has to grant permission in order to take a road trip anywhere outside of Saigon. If Intelligence indicates that such a trip would be inadvisable, this becomes the law. Even if Intelligence indicates that it is all right to go, an armed escort is required to accompany the traveler. In order to make these ground trips, advance planning is necessary to acquire Intelligence permission and for arrangements to be made for a suitable armed escort. This is not a personal choice and is beyond the control or the responsibility of the individual. Thus, opportunities for close inspection were relatively rare.

Remember, too, that the greatest effect achievable or to be expected under any circumstances as a result of chemical sprays may be roughly compared with the condition of a US hardwood deciduous forest in winter. A much better appreciation of this condition, insofar as it pertains to increased visibility, can be obtained by viewing such a forest with snow on the ground, whether it is seen from the ground or from the air. Such an effect, if achieved, may be transitory, not because the "killed" vegetation comes back to life but because of seeds giving rise to new plants and because understory species that received sublethal quantities of spray are capable of growth to fill in areas formerly dominated by the killed trees. The rapidity of this regrowth will be dependent on the prevailing growth conditions and would be expected to be more rapid during a rainy season.

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The rating of effectiveness of the 2,4-D and 2,4,5-T chemical tests is therefore based on the above factors and is primarily concerned with the killing effect of the chemicals. As the kill developed to a maximum, observations were made in the best manner available or possible. It was not always possible to obtain colored photographs because of light conditions, rainstorms, other missions of higher priority cancelling planned air trips, or lack of communication and/or understanding achieved with VN pilots as to positions of the aircraft desired in relation to the sun in order to get the best pictures. Efforts were made to take enough pictures so that slides could be furnished to the MAGRD-CDTC, to ARPA, and to Crops Division, Biological Laboratories.

The killing effect of the 2,4-D and 2,4,5-T chemicals should not be confused with "degree of defoliation" or "increase in visibility" as such. It does follow, however, that a reasonable or high percentage of kill of the vegetation (including roots) will ultimately lead to a reasonable or high degree of improvement in visibility despite the fact that in transition certain species may die but not drop their leaves. Nevertheless, other natural causes can bring about the falling of dried, dead leaves such as high winds or heavy rains. In this connection a VN agricultural official estimated that under natural conditions as many as 90 per cent of the jungle species do not ordinarily drop their leaves in concert in any given season. These leaves are dropped only as their physiological condition naturally deteriorates.

The action of cacodylic acid (CA) in tests detailed below requires an approach of understanding that differs from that for the action of the 2,4-D and 2,4,5-T chemicals. CA appears to be a desiccant in its action; that is, on contact with the foliage in sufficient quantity, drying and shrivelling of the leaves occurs relatively soon compared with the time required for this to occur as a result of exposure to the previous chemicals. Environment and growth factors affecting the vegetation appear to have a relatively small effect on the action of CA on the foliage. However, no tests with this material were exposed to heavy rain following application (the material, called ANSAR, is fairly soluble in water). So the tests with CA were rated on the over-all ability to cause desiccation of the foliage only. It is entirely possible that even though all the foliage of a substantial portion of the vegetation was dried, the implication that the vegetation was killed is not warranted until conditions for active growth return. The rating of this chemical was, therefore, on its effectiveness in drying the green foliage.

B. VARIABLES

In the tests that follow it should be readily apparent that many variables are beyond control. Once the spray has left the nozzles no control exists. Even the most exact planning as to:

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Swath width and length,
 Ground deposition rate desired,
 Amount of chemical required,
 Flow rate,
 Particle size range,
 Altitude,
 Airspeed,
 Time of day for inversion conditions and weather, and
 Spraying the area desired (aimability)

can essentially be nullified unless at least reasonable adherence to standards for these factors is in fact obtained. Many of these factors are inextricably related and one can never be entirely sure of what has been achieved in the way of performance of equipment of equipment (especially if it has not been calibrated) or in spray deposition except by judging the over-all biological result. It is too frequently impossible in judging this result to pin down a single cause for failure to achieve an optimal effect. On the other hand, if the effect is good, it follows that all of these factors as well as a host of biological factors have been reasonably well met.

To exemplify the above, progress reports, memos, and other documents are presented (Sections IX through XI of the Supplement) that indicate the impressions of the writer at the time, or shortly after, the tests were performed but before the spray effect had developed. It can be easily noted, for instance, that for Test 1 on 10 August, the writer's sketch (Section X of the Supplement) of the sprayed area reflects what was planned and was requested of the pilots. The writer was told by the pilots that the sketch was reasonably accurate. The VN Province Chief, however, later presented his sketch of the sprayed area (just after the mission), which was proved to be much more accurate by aerial observation on 28 August and was so reported after that time (Section XI of the Supplement). It should be noted that five passengers were aboard the H-34, three of whom were VN. The sense of curiosity is generally highly developed in these people and the doorway of the H-34 is not large. Additionally, the 200-gallon HIDA tank is carried internally opposite the door. Suffice it to say, the writer's observations were made from the fourth best available place of observation and Mr. Johnson had none.

In regard to Test 2, the reports written after spraying but before spray effect was evident (Sections XI, XII, and XIII of the Supplement) include an unintentional deviation from the plan but reflects an effort to present the

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facts with a conversion to linear distance based on the 2 minutes 45 seconds of spraying time at an air speed of 120 miles per hour. The spraying time information was supplied by Sgt. Roe and later Captain Cadoni confirmed that the first pass was made at an altitude closer to 125 feet than the 75 feet requested. Because the observer was on the ground at the time, he was unable to talk with these men until some time (a day or so) after the spray was delivered.

The point is made that in executing these experiments, where the writer was responsible and desirous of trying to control the variables as much as possible, the flights were performed by others. Although their full cooperation and effort was appreciated, variations could not be prevented from affecting the operation.

Later, when the USAF "operational testing" was performed (Appendix, Part B), technical guidance leading to these "tests" could scarcely enter the echelons, much less influence them. The USAF spray pilots were the major point of contact and were as cooperative as they could be under the circumstances but they, of course, had to be and were responsive to USAF orders. Some of these men had seen, and appreciated what they saw, of the vegetation control at Camp Drum, New York. This work is reviewed in a five-minute movie with sound. A copy was left in Vietnam and a copy was forwarded to ARPA in early March. In this connection, Section II of the Supplement indicates the state of the art as of 24 February 1960, and was prepared for information in response to a query originating in the US Third Army area pertinent to a Fort Stewart, Georgia, vegetation problem. X

The tests detailed in the Appendix had as their ultimate purpose the improvement or visibility from the air and on the ground in the kinds of vegetation encountered in Vietnam along roadsides, in jungles, and in mangrove areas. The chemicals used in most tests, and recommended for large-scale use, are vegetation killers of the growth-regulating type. The implication is inherent that killed vegetation would allow improved visibility in one to two months and be relatively long lasting, depending on the degree of kill achieved. It had been indicated to the writer before he left the US in July that time for effect of the sprays to develop was not critical.

For general locations of test sites the reader is referred to the marked map of Free Vietnam in Section XIV of the Supplement. Section VII presents the chronology of tests in tabular form.

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V. DISCUSSION

It should be noted that other tests were performed in addition to the 18 already listed; however, it was not always possible to revisit and observe results and the record for these is therefore incomplete. In some instances informal information was received concerning these and in each case the response was favorable. Word appeared to get around and this gave rise to requests from many areas for "testing." Obviously, these could not be allowed to interfere with the scheduling of the major efforts, although some were accommodated if they were feasible and could contribute to the research effort. Several were referred to the US-VN planning committee for consideration as to whether they should be included in target selections.

The major record of results consists of colored slides, several of which were distributed some months ago. It is planned as soon as possible to make available duplicate sets covering the entire period. A reasonably complete set has been arranged and left with MAGED-CDTC.

In connection with the one aerial spray of cacodylic acid (Test 13), the writer could not in conscience recommend unlimited use of this material for spraying jungles or roadsides at ten pounds per acre because more research information is needed on duration of effects, safety of handling, compatibility with systems (the material is corrosive to brass; the HIDAL has a fiber glass tank and stainless steel booms, but some brass connections and brass nozzles) and, most important, toxicity to humans and animals either by contact, inhalation, or ingestion. To the writer's knowledge this test was the first aerial release of this chemical anywhere at rates of this magnitude. Toxicity test information by others indicates that this material is less toxic than DDT. Its action on foliage at this rate appears to be that of a desiccant, with little evidence of selectivity among the unknown jungle species that were sprayed. About one month after spraying there was some evidence of new leaves appearing on certain species where the old foliage which had been sprayed was totally brown and shrivelled, or had fallen.

Although the sprays delivered under USAF control were not the official responsibility of the writer, it is unfortunate that certain technical aspects pertinent to the spraying could not be communicated or, if communicated, appropriate appreciation appeared lacking.

For instance, the chemicals had been represented by the writer as "vegetation control agents" or "vegetation killers" and not "defoliants," yet on 17 January (after sprays by the C-123 equipment on 14 and 15 January) a VN letter of protest was received from a rubber plantation claiming that 60,000 rubber trees had been killed. This seemed to surprise all concerned. The writer was approached after the fact, yet he had not known which particular targets had been selected for spraying. Otherwise, he could have advised against spraying jungle in proximity to a rubber plantation. (In this

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connection, it definitely appears from the evidence available that the plantation was not directly sprayed, but the concentration of vapors from the chemicals was sufficiently high to affect the rubber trees when the prevailing wind reversed direction some four or five hours after spraying). Many times extreme care was urged by the writer both on target selection and on spraying to avoid areas known to have such crops as citrus, rubber, tobacco, bananas, sweet potatoes, manioc, pappas, grapes, melons, rice, and the like. Perhaps this instance served an expensive but useful purpose in making the point. Many of these crops are far more sensitive to the spray or its vapor than the various unknown jungle species appear to be.

Another instance is that the C-123 equipment had not been calibrated for spraying the relatively viscous materials for which it was being used for the first time. This need was pointed out several times to several people; nevertheless, the system was still not calibrated when a second set of targets was sprayed in mid-February.

The onset of the dry season reached proportions toward the end of January that prompted a memorandum to the Chief, R&D Division, on 29 January (Section XV of the Supplement). This memorandum was brought to the attention of MAAG G3 the following morning.

The dry season markedly curtailed growth of upland species by the end of January. However, there were areas sprayed by the C-123's in the middle of January where very good effects were observed, namely, in two mangrove areas where lack of water did not limit growth. By mid-February large areas of mangrove were leafless.

During this assignment the writer was subjected to many preconceived notions and misconceptions from others on the general subject of "defoliation." Some felt that if "defoliation" did not remove the trees or cause them to fall, the research was useless — either total visibility or none. Others were intermediate in attitude, granting that vertical visibility would be improved but unable to visualize improved horizontal visibility. The ones who said "any increase in visibility would be worthwhile" were those who were faced with fighting in dense vegetation or being ambushed from it, or pilots or aerial photographers who needed to see down through it. (It should be noted that successful enemy ambushes have been conducted without firearms in hand-to-hand combat.)

Progressing from "defoliation" (an all-purpose defoliant has yet to be discovered) to "vegetation control" (killing the vegetation) seemed beyond comprehension for some, and when it was stated that two to six or eight weeks might be required for a major improvement in visibility, the reaction was most negative. That the French spent huge sums of money unsuccessfully fighting for several years an enemy they couldn't see in the jungle made no apparent difference. The current conflict does not seem to be nearing a successful conclusion; on the contrary, the intensity of the conflict appears to be increasing. Under these conditions it appears that the combat success

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of friendly forces should be expedited if possible by improved visibility in fighting areas, or by exposing enemy roadside ambushes, jungle trails or bases if that improved visibility can be feasibly provided. Unfortunately, the rainfall maps (Section XVI of the Supplement) were not available to the writer before the ground observation trip on Route 15 on 26 January (Section XV). Searches for other technical literature had been so disappointing that it did not seem possible that rainfall maps would be available. Nevertheless, the data they contain for the dry months of December through February certainly indicate that growth-regulator chemicals would have their immediate action impaired to a marked degree. Soil moisture continually diminishes, with only one inch or less of rain per month on the average for large areas. December had some residual moisture carry-over from November and October, but January and February show exceedingly dim prospects for active growth. Thus, the USAF spraying was started in upland areas during the worst time of the whole year (mid-January) from the standpoint of immediate chemical effectiveness. Because a high percentage of the jungle species do not ordinarily drop their leaves at any given time in the year (according to the VN authority listed in Paragraph 4 of Section XV of the Supplement), a distinct possibility exists that the action of the chemicals already sprayed will become obvious where conditions again favor growth. Mangrove areas along Route 15, where lack of water is not limiting, were successfully sprayed in the same period (mid-January) and excellent results were apparent in two weeks, with a very high percentage of the sprayed mangrove denuded in one month.

VI. CONCLUSIONS

In relation to the work reported here it is concluded that:

1. In general, with regard to the total program,

a. The chemicals recommended for use, namely the esters of 2,4-D and 2,4,5-T, are sufficiently active to kill a majority of species* encountered in Vietnam if:

(1) They are applied properly to the vegetation

(2) They are applied during a period of active growth of the vegetation.

b. Color photography is the best means of recording the effects of sprayed chemicals, but even the best picture can fall short of being fully descriptive.

2. In regard to the research work conducted during both work periods, it can be concluded that:

a. Chemicals of the type being used are fully effective only when the vegetation is in a period of active growth (See Sections I, XV, and XVI of the Supplement). Lack of rainfall in the period between December and February induces a state of dormancy, and spraying should be curtailed during this period. Spraying of mangrove or other species growing where water is plentiful could continue.

b. Chemicals of promise have been tested successfully on a small scale, but more information concerning their use must be obtained through additional research (See Tests 14 and 16 in the Appendix). Extra-continental and in-house research in this area should continue. Especial attention should be paid to cacodylic acid as one of the immediately available and promising candidates. Further testing with Diquat is indicated; however, this product is currently available only in restricted quantities.

c. Technical information must be included in effective decision-making. Its lack may result in inefficient use of chemicals or may have serious economic or public health consequences (See Appendix, Part B).

d. Incorporation in the HIDAL and the C-47 spray system of a flow meter showing rate of flow (gallons per minute) as well as the gallonage sprayed would be a useful device in spraying liquids of various viscosities. Calibration of these systems with the chemicals to be used is desirable.

* See Sections II, XIII, and XV of the Supplement.

e. The HIDAL equipment can serve a useful purpose, but could be improved if it had a higher flow rate, especially if such higher flow rate could be adjusted for several rates for dispensing solutions of various viscosities (See Appendix, Tests 1, 13, and 14).

f. The C-47 system could be made useful if it were re-engineered to provide greater versatility in spraying adequate quantities of the required solutions (See Supplement, Section II.).

g. The 14B spray tank would be of greater use if it were simpler and more easily assembled, checked out, and operated (See Appendix, Test 2).

h. Continuous spray booms for fixed-wing aircraft (across and under the fuselage) would allow greater freedom of choice of altitude for spray releases (See Appendix, Tests 7 and 8).

3. In relation to the operational portion of the second work phase as conducted by the USAF (See Appendix, Part B), it can be concluded that:

a. The recommended chemicals will work effectively, as demonstrated by the two operational tests on mangrove that were actively growing in swamp areas.

b. The chemical effect is seriously limited by dormancy in vegetation, as evidenced by four operational tests on upland vegetation that was dormant because of drought (See Supplement, Section XV).

c. The C-123/Hourglass system should be calibrated for spraying the recommended materials. Additionally, the inclusion of a flow rate meter in the system would enhance its experimental and operational use for solutions of different viscosities (See Supplement, Section XV).

d. Operational tests with uncalibrated equipment can provide only minimum information because application rates remain uncertain. Thus, logistic and operational factors for future operations cannot be predicted (See Supplement, Section XV, and Section IV, B of this text).

e. Operational tests must be guided by adequate technical advice until operational elements achieve a higher degree of familiarity with the materials and the effects of climate, vegetation types, and associated factors (See Supplement, Section XVII).

VII. RECOMMENDATIONS

On the basis of the work done in South Vietnam and the resulting conclusions, it is believed that the following recommendations merit careful consideration and implementation.

1. That the use of appropriate formulations of 2,4-D and 2,4,5-T be exploited for immediate use pending development of more active and rapid-acting chemicals. Simultaneously, explore the possibility of enhancing the effectiveness of these formulations by suitable additives.
2. That research work be conducted toward finding more rapid acting and effective chemicals for defoliation and plant killing.
3. That these chemicals be screened in areas such as Vietnam, Thailand, or other countries with similar vegetational types, as well as in temperate areas, because of the wide variation in vegetation response depending upon species, climate, and other associated factors. The required research could be performed with less interference in a country at peace.
4. That both the extra-continental research and the screening programs, as well as any future operational tests, be guided in all stages by competent technical advice. It is necessary that these technical advisors be on the scene and that they have a major voice in decisions. This is especially important when the safety of economic crops, possible toxicity, and validity of scientific data are concerned.
5. A technically qualified civilian staff be developed for this increase in effort. It is currently estimated that a minimum of 12 civilians is required, supported where necessary by an adequate number of military personnel, in order to handle all phases of the work including in-house screening, contract monitoring, and test-site operations.
6. At each test site the research should be conducted under the direct supervision of a civilian scientist supported by a staff composed of at least three technically trained civilians and a sufficient number of military personnel to support the effort. The lack of an adequate-sized technical staff hampered the accomplishment of the research objectives in Vietnam during the research phase and prior to USAF spray operations.
7. Thoroughly evaluated cacodylic acid and Diquat, two promising candidate agents, as soon as possible in order to exploit their potential.
8. That the HIDAL be re-engineered to provide increased flow rates as required to achieve adequate deposition of the necessary chemicals and that provision be incorporated to adjust flow rates as necessary.
9. Accurately and completely calibrate all spray devices prior to use for flow rate, droplet size, etc, using the actual chemical solutions or simulants with identical physical properties.

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10. Provide a professional photographer to record results of tests with color photos.

11. Assign a helicopter and a light aircraft (L-20 or similar type), complete with operational and maintenance crews, to the civilian scientist in charge for use in spray missions and for aerial observations of results.

12. Continue to improve disseminating devices for both aerial and ground use.

13. Include the civilian scientist in charge in all decision-making discussions pertaining to use of vegetational sprays.

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APPENDIX

A. DETAILS OF TESTS

1. Test 1

a. Description

Date of Spray: 10 August 1961, about 1650 hours.

Place: Roadside areas north of Kontum. The vegetation consisted of relatively dense upland forest species with trees from 10 to 60 feet tall; species unknown.

Chemical Sprayed: It was planned to spray Dinoxol for deposit rates of one and two gallons per acre (four and eight pounds per acre). This was to be accomplished by overlapping a portion of two separate swaths. Despite the plan, the following was achieved. A total of 50 gallons of Dinoxol was sprayed for an estimated swath width of 200 feet, laying separate single-pass swaths on each side of the road with no overlap. Deposited evenly over a 200-foot swath, at one gallon per acre, 50 gallons of chemical could be sprayed for a distance of about two miles. Measurements of the area actually sprayed were impossible to obtain.

Equipment: H-34 helicopter equipped with HIAL (Helicopter Insecticide Dispersal Apparatus, Liquid).

Flow Rate: According to the literature, light oil sprays are used, the system is relatively fixed for delivering one-half gallon of spray per acre if flown at about 50 knots at an altitude of about 75 feet. Other rates are possible by varying airspeed and altitude or spraying the same swath twice, but little data were available for adjustment. The pump pressure was 40 pounds. With less viscous liquids a flow rate of about 25 gallons per minute has been obtained.

Airspeed: Requested 50, obtained 45 knots.

Altitude: Requested 75 feet, varied between 50 and 100.

Wind: Crosswind very light from the west, estimated at less than 5 knots.

Weather: Overcast and cloudy. A rainshower was observed a mile or two east of the area which, the writer was informed, later passed over the sprayed area.

Observation Dates: Aerial flyover, 28 August; ground trip, 11 October.

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b. Results

Very good to excellent effects were observed on 28 August, the area being visible from the air on approach from a distance of about 5 miles. No evidence was observed of overlapping swaths, nor were the swaths of equal length or adjacent to one another along the road. The vegetation showed clearly that leaves were turning brown.

It is estimated that 70 per cent of the trees were either dead or dying on 11 October.

c. Discussion

It was not possible to observe the results of these sprays with greater frequency because of several interfering factors. The site was quite distant and communications were intermittent at best; thus arrangements for ground security were difficult for the VN to make, especially when VC (enemy) activity was fairly frequent and often extensive in this region.* The airstrip at Kontum was often closed for relatively long periods because of the rainy season.

After the spray mission the HEDAL was grounded because of damage to the H-34 fuselage. It was not until 12 January 1962 that it was used again. Its performance on three tests (1, 13, 14) was excellent as judged by the results achieved.

Figures 1 through 4 show the results of Test 1 two months after the roadside north of Kontum was sprayed with Dinorol with the HEDAL and H-34 helicopter.

* Reference: "Weekly Intelligence Digest," No. 41-61 of the Pacific Command. 20 Oct 1961, pages 8-10.