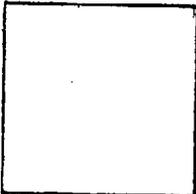


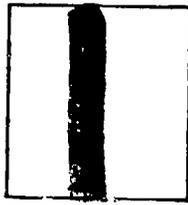
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REPORT

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REVIEW AND EVALUATION OF ARPA/OSD "DEFOLIATION" PROGRAM

Research Phase : 15 July 1961 - 12 January 1962

Operational Phase: 13 January 1962 - March 1962

in

SOUTH VIETNAM

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SUMMARY REPORT

Review and Evaluation of ARPA/OSD "Defoliation" Program

in South Vietnam

Research Phase: 15 July 1961 to 12 Jan. 1962

Operational Phase: 13 Jan. 1962 to 15 Jul. 1962

A group of technically trained and professionally experienced individuals was selected by ARPA on direction of OSD to thoroughly investigate the "Defoliant" program carried out in South Vietnam in two phases (Research and Operational), sometimes referred to as Task 20.

The team was charged with the mission of (a) determining the effectiveness of the herbicides on various types of tropical vegetation, (b) assessing the results as to effectiveness of the chemicals in improving the vertical and horizontal visibility from the air and ground, and (c) recommending a research program needed to further exploit the employment of herbicides for vegetation kill and defoliation.

The Evaluation Team began its investigation on 7 April and terminated its observation of sprayed targets on 18 April 1962.

The report was written in three parts: Part I dealing with the "State of the Art" in the use of herbicides in control of vegetation; Part II, findings, evaluations and assessments; Part III, Conclusions and Recommendations.

STATE OF THE ART

Major Uses of Herbicides

Highly effective herbicides are available for killing crops and undesirable vegetation in varied environments for military purposes. The successful use of herbicides depends upon a knowledge of the scientific disciplines involved, the artful use of available technology, strict adherence to the principles of treatment methods, and effective program planning and management.

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In 1961, more than 50 million acres of crop and non-croplands in the United States were treated with about 100 million pounds of herbicides at a cost of about 200 million dollars. The phenoxy herbicides, such as 2,4-D and 2,4,5-T that have been employed in South Vietnam are used for the control of weeds and undesirable vegetation on about 40 million acres of crops, rangelands, forests and non-cropland each year. In addition, hundreds of thousands of miles of roadside, railroad and utility line rights-of-way are also treated each year. Of the total acres treated each year with the phenoxy herbicides, aircraft are used to treat more than 10 million acres, an area half as large as South Vietnam.

How Phenoxy Herbicides Kill Plants

Herbicides kill plants by interfering with essential physiological processes, such as respiration and photosynthesis, and by inhibiting the synthesis and use of metabolites essential to plant growth. The phenoxy herbicides kill plants by multiple effects including the proliferation of cells, loss of apical dominance, and the conversion of stored carbohydrates such as starch to soluble sugars.

The herbicides 2,4-D and 2,4,5-T kill plants by both systemic and contact action. Applied to the foliage of rapidly growing plants, 2,4-D and 2,4,5-T enter the leaves and stems and move downward to the roots, killing the entire plant. Applied to the soil, they are also readily absorbed by plant roots and move to the tops, resulting in complete kill of the plant. The phenoxy herbicides will also kill plants by contact and systemic action when applied in fine droplets at high rates per acre. When used in this manner they will cause desiccation of foliage which may or may not be accompanied by defoliation depending on the mixture of plant species present and growing conditions.

When 2,4-D and 2,4,5-T are applied to the foliage of semi-dormant or dormant plants, their effectiveness in killing vegetation is critically reduced. However, when they are applied to the foliage of rapidly growing vegetation, 2,4-D and 2,4,5-T move downward into the lower leaves, stems and roots along with the carbohydrates resulting from photosynthesis in the leaves.

Since 2,4-D and 2,4,5-T are systemic, translocated herbicides that kill plants by multiple causes, their early effects (1 to 2 weeks) are not as spectacular as the desiccating and burning effects of contact herbicides. For this reason, and because of their mode of action, it is impossible to evaluate their initial effects on perennial woody vegetation earlier than 30 days after treatment and their full effects in killing the vegetation can not be completely evaluated until at least 1 year after treatment.

Equipment

Herbicides are applied in the United States in spray or granular form by either aircraft or ground equipment. Aerial applications are generally

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made by small commercial single engine agricultural airplanes, or helicopters. Treatments are made only when inversion temperature conditions exist and wind is less than 5 mph. To further reduce hazard of drift and insure good deposition recommended spray volumes are 3 to 5 gallons or more per acre and droplet size 300 microns or larger.

EVALUATION

Characteristics of the Vegetation

Evergreen forests, mangroves, and tropical scrub are of immediate importance in vegetation control in South Vietnam. The arrangement of the forest canopy and undergrowth in layers; the high density of the total plant cover; the great number of kinds of plants; and the high total volume of plant material are of great importance.

Nearly all plants of the Vietnamese forests can be controlled with herbicides in reasonable amounts; some trees require larger amounts than others. Unless applied during active growth, herbicides are much less effective. Active growth corresponds generally to the rainy season.

Plants killed by herbicides will be replaced by other kinds of plants unless the soil is cultivated or treatments repeated. Shrubs, tropical grasses, or small bamboos often constitute a very difficult control problem. Repeat treatments, probably annually, will be required to keep an area free of vegetation.

Trunks of trees, vines, and other vegetation killed by herbicides will remain. This material cannot be burned without falling, the trees to improve fuel structure and burning properties. Research knowledge and operational experience of forest fire protection agencies in the United States will aid in solving this problem.

Method of Evaluation

Effectiveness of herbicide treatments was evaluated on the basis of: defoliation, canopy kill, vertical visibility, horizontal visibility, and distribution of herbicide. For each target each of these factors was assigned a numerical rating between zero (no effect) and 100 per cent (complete effect). Individual ratings were averaged and rounded to the nearest whole number (Appendix A, and Table 4, Summary of Target Evaluation).

Each team member made written observations on characteristics of the vegetation, including response to herbicides; drift and nature of effects of herbicide outside target areas; and cutting, burning, or other activity of local populations after herbicide treatments. These observations were utilized in evaluating effectiveness of the treatments.

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The criterion for "defoliation" was the degree to which leaves were actually caused to fall from the plant.

Effectiveness of the herbicides in producing defoliation was estimated on the basis of a comparison in leaf fall from trees in adjacent treated and untreated areas. In some portions of some targets, and on certain kinds of plants, leaves were shriveled and dried but still adhered to the plant. In other portions of a target, trees that were tolerant of the quantity of herbicide received had lost few if any leaves from the spray. In other cases trees had lost all their leaves. The entire target area that it was intended to spray was evaluated as a single unit, including skips as well as treated portions.

The criterion for "canopy kill" was death of the above-ground portions of the plant. During ground observations dead trees could be differentiated from those which were merely defoliated and desiccated by cutting into lower branches, trunks, or root collars at ground level. A determination of the probability of a tree dying or living could be made on the basis of discoloration of tissue at the points of such cutting, caused by translocation of the herbicide. In aerial observations the basis for this rating was essentially the same as for defoliation, taking into consideration the results of ground observations made as above.

The criterion for "vertical visibility" was the estimated percentage of the ground that could be seen when a sprayed area was observed from directly above, in comparison with an adjacent unsprayed area.

The criterion for "horizontal visibility" was the improvement in the ability of an observer to see and recognize objects at or near ground level some distance from himself as affected by the density of the vegetation in treated areas compared with adjacent untreated areas.

The criteria for "distribution of the herbicides" were: the response of the above ground vegetation from the soil surface to the top of the tallest tree (vertical distribution), (b) the response of the upper vegetation canopy to lack of uniformity of deposit in the spray swath and "skipped areas" on the target (horizontal distribution), and (c) the response of vegetation and crops outside the intended target to drift.

Evaluation of Target Results

A thorough and intensive evaluation of 21 targets in 11 observational areas showed that, when evaluated from the air, the herbicides were approximately seventy percent (70%) effective (range 50 to 90%) in accomplishing the objectives that had been established and, when observed on the ground, they were sixty percent (60%) effective (range 30 to 80%). The evaluation of the targets are summarized in Table 4.

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Detailed data on the individual targets evaluated by the team are contained in Appendix A. Location, kind of vegetation, treatment, and other information are presented, in addition to the numerical ratings.

It is obvious from the results observed and reported in Table 4 that significant improvements in vegetation control can be expected from modifications which will (1) reduce spray drift, (2) increase spray deposit in the intended spray swath, (3) increase the volume and acid equivalent per acre, and (4) apply the herbicide to actively growing rather than dormant vegetation.

Evaluation

Aerial applications were made with either the Fairchild C-123, Douglas C-47, Douglas AD-6 airplanes, or Sikorsky H-34 helicopter. A Buffalo Turbine sprayer was used for ground applications.

The aircraft spray equipment, designed to disperse liquids the viscosity of fuel at one gallon per acre, had to be operated "full out" to deliver 1 gallon or less per acre of the herbicides used, because of their higher viscosity.

Nozzle size and arrangement produced spray droplets considerably finer than 300 microns diameter, resulting in excessive drift and loss of herbicide from some targets.

Immediate minor modifications were suggested to increase droplet size and delivery. Major modification will be required on each type of aircraft dispersal equipment to make it capable of delivering 3 gallons of viscous herbicide liquid per acre.

Suggestions were made for further use of the Buffalo Turbine and MC-1 tank and pump assembly removed from the C-123, as ground hydraulic sprayers, by equipping them with suitable hose and spray gun type nozzles.

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Table 4. Summary of Target Evaluations 1/

Evaluation Criteria	<u>Aerial Observations 2/</u>											Evaluation Criteria Av. 3/
	1	2	3	4	5	6	7	8	9	10	11	
1. Defoliation	60	70	80	70	70	70	90	90	90	90	80	80
2. Canopy Kill	60	70	80	60	70	60	90	90	90	80	90	80
3. Vertical Visibility	60	60	80	70	80	60	80	90	90	90	80	80
4. Distribution of Herbicide	30	60	70	40	70	40	80	60	80	70	60	60
5. Total Target Effectiveness	50	70	80	60	70	60	90	80	90	80	80	70

	<u>Ground Observations 2/</u>											
	1	2	3	4	5	6	7	8	9	10	11	
1. Defoliation	40	2/	70	70	70	50	90	2/	2/	2/	80	70
2. Canopy Kill	40		70	70	80	40	90				80	70
3. Horizontal Visibility	40		50	60	70	40	60				60	50
4. Distribution of Herbicide	10		60	30	80	40	80				60	50
5. Total Target Effectiveness	30		60	60	80	40	80				70	60

NOTES:

- 1/ A rating scale of 0 to 100 percent was used in evaluating the targets. 0 - No effect; 100 - 100 percent effectiveness. Each figure for each target criterion is the mean team rating. See Appendix A for a detailed description and rating of each target.
- 2/ The targets observed from the air and ground were identical and numbered to permit comparative ratings. All of the eleven (11) target observations were rated from the air; however, target observations 2, 8, 9 and 10 were not rated on the ground.
- 3/ Mean rating values were rounded to the nearest whole number.

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PART THREE:

CONCLUSIONS AND RECOMMENDATIONS

I. Conclusions

The results of the team's evaluation of the effectiveness of herbicides in controlling vegetation in South Vietnam strongly support the following conclusions:

1. Evidence examined and evaluated shows conclusively that if properly applied at suitable rates with proper equipment, herbicides unquestionably can be used to control vegetation. The operational program of vegetation control should be continued, provided the modifications in techniques and equipment recommended by the technical evaluation team are made.

2. A thorough and intensive evaluation of twenty-one targets in eleven observational areas showed that when evaluated from the air, the herbicides were approximately seventy per cent effective in accomplishing the objectives that had been established; and when evaluated on the ground they were sixty per cent effective. Based on research results and use in the United States, and limited employment in South Vietnam, when properly used these herbicides can produce very significant results in twenty to sixty days, depending on the kind of vegetation.

3. One of the most important limiting factors in reducing effectiveness in achieving the full objectives of the research and operational programs was the dispersal equipment. This equipment was designed to

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deliver approximately one gallon per acre of liquids with viscosity similar to fuel oil, in fine droplets. This volume of one gallon per acre, in fine droplets, did not result in an adequate deposit of herbicide of the viscosity used, for optimum control of all types of mixed tropical vegetation in South Vietnam. Therefore modification of the equipment will be required. All aircraft used are suitable for herbicide application if equipped with adequate dispersal equipment. Fine spray droplets and poor nozzle arrangement on the aircraft resulted in excessive loss of the herbicides by drift.

4. Another very important limiting factor in controlling the vegetation was that in some cases the herbicides were applied during the period when the plants were dormant.

5. Plants differ in their tolerance to herbicides and these differences must be taken into account in planning vegetation control and evaluating effects of herbicides. Since systemic herbicides, such as Purple, continue to exert their effects over a long period of time, evaluation cannot be made within a short time after application. Initial evaluation should not be made in less than thirty days and final evaluation in less than one year after treatment.

6. The amount of Purple used per acre gave excellent control of mangrove, but the active ingredients and volume applied per acre were not adequate to give maximum effectiveness in killing evergreen forest and tropical scrub when dormant. When properly employed, herbicides are capable of killing most plant species encountered in the forests of

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Vietnam, but the dead trunks and other vegetation still remain and impair visibility. It may be feasible to develop effective techniques for improving the fuel structure so the woody material can be disposed of by burning or other means.

7. Additional basic information is needed on herbicides, equipment, and vegetation to improve the effectiveness of vegetation control and develop an operational capability in tropical regions. The conditions prevailing in South Vietnam preclude the conduct of an effective research program which is critically needed. Results achieved in vegetation control and problems encountered in South Vietnam demonstrate conclusively that an intensive program of research must be initiated without delay in localities where there is ready access to the experimental areas.

8. The Evaluation Team did not see or examine any areas where food plants had been treated with herbicides. Based on extensive research conducted in the United States and in many tropical and non-tropical countries, the technical feasibility of killing all crops in South Vietnam with herbicides at any time during their life cycle prior to the production of edible portions is well established. The herbicides necessary are now in military stocks. However, other herbicides are available commercially with which crops in selected areas can be killed without damage to crops of the same kind in nearby areas.

II. Recommendations

The Evaluation Team makes the following recommendations with respect to:

- A. An operational program of vegetation control ---

1. It is strongly recommended that the operational phase of the vegetation control program in South Vietnam be resumed immediately, provided:

a. That minor modifications on the MC-1 dispersal equipment on the C-123 aircraft and the dispersal equipment of all other operational aircraft be changed immediately to deliver a volume of approximately one and one half (1 1/2) gallons per acre of Purple, in accordance with suggested modifications in this report.

b. That the aircraft which is delivering 1 1/2 gallons per acre make two passes on each target by applying one-half the load and immediately respraying the same swath with the second half of the load, in order to deliver a total volume of 3 gallons per acre on the vegetation.

c. That the dispersal equipment nozzles be modified to deliver droplets of approximately 300 micron size.

2. That as soon as possible a team of three specialists be obtained from the United States to provide technical assistance to the operational program:

- a. Chemical weed and vegetation control specialist
- b. Agricultural aircraft spray equipment specialist
- c. Tropical vegetation specialist

3. That a complete "target analysis" of each area to be treated be made with the assistance of the qualified specialists to determine:

- a. Stage of growth and kind of vegetation.
- b. Selection of herbicide.
- c. Rate of herbicide active ingredients and total volume of spray per acre.

d. The susceptibility of and hazard to adjacent crops and desirable vegetation.

e. Selection of appropriate dispersal equipment.

f. Meteorological conditions, including atmospheric stability.

4. It is strongly recommended that vegetation be treated with herbicides during its period of active growth.

a. Evergreen forest and tropical scrub should be treated when they are actively growing. The period of active growth generally coincides with the rainy season. It is pointed out that the rainy season occurs at different times of the year in different parts of South Vietnam.

b. However, available information indicates that mangrove forest may be treated with herbicides at any time regardless of growing season.

5. Small plots, roadside areas, rights-of-way, and similar areas should be treated with ground type equipment utilizing the information given in this report.

6. That, to afford adequate opportunity for the systemic herbicides employed to exert their full effect, no cutting or burning of treated vegetation be permitted for at least sixty (60) days, and preferably for as long as six months.

7. That, where it is necessary to maintain areas free of vegetation on a permanent basis, a maintenance program be carried out. The need for repeat treatments can be determined only by inspection and knowledge of local requirements.

a. It is probable that, if Purple is used, retreatment will be required on approximately an annual basis.

b. It is probable that the amount of herbicide required for repeat treatments will be less than required in the original.

8. That stocks of Purple and mixed Pink and Green herbicides on hand be sampled according to statistically sound methods, and the samples sent to the United States for analysis to determine the identity of the esters, the amount of each, and the total acid equivalent of 2,4-D and 2,4,5-T present per gallon.

9. That it is technically feasible to kill all of the various kinds of crops in South Vietnam with herbicides now in military stocks (Appendix C). However, other herbicides are available commercially with which crops in selected areas can be killed in South Vietnam without damage to crops of the same kind in nearby areas.

B. A program of Research and Development in vegetation control

1. That an accelerated Research and Development Program in vegetation control be initiated in the United States and Thailand to investigate the following:

a. Effectiveness of selected herbicides.

b. Effects of surfactants (surface active agents) such as soaps, detergents, emulsifiers, stickers and wetting agents.

c. Development of improved dispersal equipment for aerial and ground operations.

d. Determination of optimum rates of active ingredients, volume, and droplet size for maximum deposit and effectiveness of herbicides and mixtures on tropical vegetation.

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e. Annual cycle of growth and other ecological characteristics of tropical vegetation, especially tropical forests.

f. Feasibility of developing effective methods of using fire and other means to dispose of woody material killed by vegetation control operations.

g. Develop an aircraft dispersal system capable of delivering 3 gallons of spray volume per acre as soon as possible.

2. The research program recommended involves many aspects of the agricultural and biological sciences. Therefore, it should be planned and carried out with consultation and cooperation of governmental agencies, educational institutions, and others qualified in the agricultural and biological sciences to utilize the research information and experience of such agencies to provide mutual benefits.

3. That, prior to operational use, the final field testing of equipment, herbicides, and techniques developed in the United States and Thailand Research and Development Programs be accomplished in South Vietnam.

4. That investigations be conducted on dispersing systems for herbicides in solid, liquid, or vapor form for use in attacking small plantings of food crops.

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REVIEW AND EVALUATION of ARPA/OSD "DEFOLIATION" PROGRAM

Research Phase: 15 July 1961 — 12 January 1962

Operational Phase: 13 January 1962 — March 1962

in SOUTH VIETNAM.

INTRODUCTION

I. General Background

1. Following some apparent deficiencies, including criticisms and adverse newspaper publicity in the use of certain chemical compounds (herbicides) for the purpose of defoliation in designated areas of South Vietnam, a group of technically trained and professionally experienced individuals were selected by ARPA on direction of the Office Secretary of Defense to thoroughly investigate the matter and to prepare a report of their findings. Brigadier General Fred J. Delmore was designated group leader by ARPA.

2. The research phase of the project as set up in South Vietnam was known as Task No. 20 and was carried out under the jurisdiction of R&D division of MAAG. It had for its objective, to determine the feasibility in the use of chemicals applied as sprays by aircraft or ground equipment against tropical vegetation in selected target areas in South Vietnam for the purpose of improving roadside and jungle visibility to aid in aerial and ground surveillance of routes of enemy movement and supply, to reduce ambush opportunities for the enemy, and to aid in exposing enemy jungle bases.

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3. The team members were given complete individual freedom of action in making observations, kinds of information to be obtained, collection of information and evaluation and presentation of results. It was emphasized again and again that each member of the team was free to disagree with any conclusion of other team members, and each was encouraged to submit a minority statement or report on any phase of the subject under investigation.

4. The report was prepared in two parts. Part One deals with the "State of the Art" of vegetation control: background information, general principles, and the current status of the use of certain herbicides in vegetation control as presently known to science. Part Two presents data collected by the team in the field; the analysis, discussion, and conclusions drawn from these data; and recommendations by the team (a) to institute an effective interim program of vegetation control in South Vietnam, and (b) to provide for concurrent research and development work to yield information required for successful vegetation control in tropical regions.

II. Team Objectives

1. To survey the results of all field use of the employed chemicals between 15 July 1961 and 15 March 1962.

2. To evaluate the effectiveness of the chemicals as they pertain to the improvement of vertical visibility from the air and the improvement of horizontal visibility on the ground.

3. To evaluate the effectiveness of the chemicals for controlling various types of tropical vegetation under varying conditions of weather, climate, and growing conditions.

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4. To make definite recommendations on the following:
 - a. The potential of the employment of chemicals against tropical vegetation;
 - b. the limitations and hazards in the use of chemicals;
 - c. concentrations of chemicals in order to expect maximum effectiveness;
 - d. advantages and disadvantages in the use of mixtures of chemicals;
 - e. exploitation of various delivery and dispersing systems for the chemicals;
 - f. the use of chemicals and the method of their employment to control vegetation surrounding critical installations such as depots and buildings;
 - g. the employment of various chemicals against edible crops, covering reaction time, limitations, hazards and potentials;
 - h. nature of a research program needed to further exploit the employment of chemicals for vegetation killers and defoliants, under varying environmental conditions, and be effective within short periods of time -- days and preferably hours.

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PART ONE:

A DISCUSSION OF THE STATE OF THE ART

I. Principles in the Use of Herbicides for the Control of Vegetation

A. Major Uses of Herbicides

Highly effective herbicides are available for the control of cultivated crops and undesirable vegetation in varied environments such as non-croplands, vegetation in and around potable, irrigation, and navigable waters, and vegetation in and around military and non-military installations.

The successful and safe use of herbicides depends upon a knowledge of the state of the scientific discipline of weed and vegetation control, the art of the use of this technology, strict adherence to the details and principles of appropriate treatment methods, and effective program management. The details of control treatments differ by localities because of differences in vegetation, soils, climate, and growing conditions.

Many different types of herbicides are being used for vegetation control and many others are being evaluated experimentally to determine their usefulness. In 1961, more than 100 million pounds of herbicides were used on more than 50 million acres in the United States at a cost of about 200 million dollars to the consumer. In addition, vegetation on hundreds of thousands of miles of roadside, railroad, and utility line rights-of-way is controlled and maintained by the use of herbicides

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in the United States each year. Herbicides have proved economical and effective in controlling a wide variety of vegetation under strikingly different climatic conditions.

B. Definitions and Classification of Herbicides

As an aid to the interpretation of this report the following definition of terms may be helpful:

1. Herbicide - is a phytotoxic (toxic to plants) chemical which when applied at appropriate rates and growth stages will inhibit, control, or completely kill all or selected portions of or kinds of vegetation. Herbicides will kill perennial vegetation, but in dense, difficult to control vegetation mixtures of herbicides and repeat treatments are required for complete control.

2. Defoliant - is an agent which causes the leaves to separate and fall from plants. Defoliants normally do not kill perennial vegetation and regrowth usually occurs. There are no known chemicals which will cause rapid defoliation of mixed woody perennial vegetation.

3. Desiccant - is an agent which causes the leaves of plants to dry with or without subsequent defoliation. Desiccants normally do not kill perennial vegetation and regrowth usually occurs.

Herbicides, for the purpose of this report, may be broadly and generally classified on the basis of use as (1) contact herbicides, (2) systemic herbicides, and (3) soil sterilants. All herbicides may be either selective or non-selective depending on their rate of application.

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Contact Herbicides, are phytotoxic chemicals which when applied to the foliage of plants, are not translocated to other parts of the plant, but kill by localized action at the point of application. Such herbicides cause rapid desiccation of foliage which may or may not result in defoliation. Single applications of contact herbicides are usually not effective in killing perennial herbaceous or woody vegetation. Such herbicides are effective in controlling annual vegetation. Examples of contact herbicides are: dimethylarsinic acid (cacodylic acid); pentachlorophenol (PCP); 4,6-dinitro-o-sec-butylphenol (DMBP); and 1,1'-ethylene-2,2'-dipyridylum dibromide (diquat).

Systemic herbicides, are phytotoxic chemicals, which when applied to the foliage or roots of plants, are translocated to other parts of the plant and kill by local and systemic action. Such herbicides may move from the leaves to the roots giving a complete kill of roots and tops of plants. They may also be absorbed by the roots and translocated to the tops, killing the entire plant. High rates of systemic herbicides will often give contact action resulting in desiccation which may or may not be accompanied by defoliation. A single application of a systemic herbicide is often adequate to control annual vegetation but more than one application is usually required to give complete control of perennial herbaceous and woody vegetation. Examples of systemic herbicides are: 2,4-dichlorophenoxyacetic acid (2,4-D); 2,4,5-trichlorophenoxyacetic acid (2,4,5-T); 2,3,6-trichlorobenzoic acid (2,3,6-TBA); 2,3,6-trichlorophenylacetic acid and 2,2-dichloropropionic acid (dalapon).

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Soil sterilants are phytotoxic chemicals, which when applied to the soil with or without emerged vegetation present, kill all vegetation and possess residual action in the soil which prevents the regrowth of vegetation for periods of six months or longer. The use of these herbicides in the dry season should be avoided as moisture is required for their effective use. Examples of soil sterilants are: 5-(phenyl)-1,1-dimethylurea (fenuron); 3-(4-chlorophenyl)-1,1-dimethylurea (monuron); 2-chloro-4,6-bis(ethylamino)-s-triazine (simazine); and 3-isopropyl-5-bromo-6-methyl uracil (h-82).

Herbicides may be used for vegetation control, defoliation, and desiccation. Herbicides or mixtures of herbicides are available which will kill the tops and roots of most plants. (No herbicides or other chemicals or mixtures of chemicals are known which will cause rapid defoliation of vegetation containing a wide variety of different species.) Herbicides are available which will cause immediate desiccation of foliage without defoliation and without killing the vegetation. Herbicides may also cause some species to slowly shed their leaves if completely desiccated, while other plants may not shed their leaves even after severe desiccation and complete top kill. Some herbicides applied on mixed vegetation may cause rapid defoliation of some plant species while actually inhibiting defoliation of others.

C. Type of Phenoxy Herbicides

The phenoxy herbicides are the most widely used herbicides in the United States. The herbicidal properties of these chemicals were reported in 1944 and since that date they have been used for weed and

Control of Vegetation (defined as the kill of above and below ground parts of plants or the prevention or inhibition of plant growth for temporary or extended periods as desired).

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brush control on an aggregate of approximately 360 million acres of cropland and non-cropland. Currently these herbicides are being used on about 40 million acres of crop and non-cropland for weed and brush control each year.

Several herbicides in this group including 2,4-dichlorophenoxyacetic acid (2,4-D); 2,4,5-trichlorophenoxyacetic acid (2,4,5-T); 2-(2,4,5-trichlorophenoxy)propionic acid (silvex); and mixtures of these are widely used to control mixed dicotyledonous and annual monocotyledonous plants other than perennial grasses on non-croplands. Phenoxy herbicides are available as salts and ester derivatives. They are of low to intermediate oral toxicity (LD50 = 375 to 1,200 mg/kg).

The esters of 2,4-D and 2,4,5-T are more effective than salt formulations on hard-to-kill species especially in areas of frequent heavy rainfall. There are two types of esters of 2,4-D and 2,4,5-T: (1) the high-volatile esters such as methyl, ethyl, isopropyl, butyl, amyl and others, and (2) the low-volatile esters such as butoxyethanol, butoxyethoxypropanol, capryl, ethoxyethoxypropanol, isoctyl, propylene-glycolbutylether and others.

Under humid high temperatures (90° F) conditions favoring rapid growth, where volatility is not a hazard to adjacent or nearby crops, the high-volatile esters are equally as effective as the low-volatile esters and less expensive. The low-volatile esters are less hazardous to use than high-volatile esters in areas adjacent to or near susceptible crops when temperatures are 95° F. or less. When temperatures exceed 95° F., the vapors of both the high- and low-volatile esters will cause

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injury to nearby susceptible crops, but the low-volatile esters are much less hazardous. The herbicides 2,4-D and 2,4,5-T and mixtures containing both chemicals will kill a broad spectrum of crop plants. Precautions must be taken to prevent spray drift or vapors from coming in contact with susceptible crops or serious damage will result.

D. How Phenoxy Herbicides Kill Plants

Herbicides kill plants by interfering with essential physiological processes, such as respiration and photosynthesis, or by preventing the synthesis of metabolites, such as vitamins, which are essential for plant growth.

Herbicides such as 2,4-D and 2,4,5-T, when applied to the foliage of plants, must enter the leaves, stems or roots, and move throughout the plant for maximum kill. The penetration, absorption, movement, and effectiveness of these herbicides are influenced by many factors.

These herbicides are most effective when applied to rapidly growing vegetation. Moderate temperatures, high humidity, high rainfall, and fertile soils encourage rapid plant growth. They are least effective in killing vegetation when environmental and soil factors are unfavorable for rapid plant growth. When 2,4-D and 2,4,5-T are applied to the foliage of semi-dormant or dormant vegetation, their effectiveness is greatly reduced. Their effectiveness is correlated with the rate of plant growth prior to application, at the time of application, and for a period of 2 to 4 weeks after treatment.

When 2,4-D and 2,4,5-T are applied to the foliage of rapidly growing vegetation, the herbicides move downward into the lower leaves,

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stems, and roots with the carbohydrates resulting from photosynthesis in the leaves. If the plants are dormant and carbohydrates are not moving from the leaves to the roots, the herbicides do not move effectively downward into the roots and their effectiveness in killing vegetation is greatly reduced.

Since 2,4-D and 2,4,5-T are systemic, translocated herbicides, their early effects (1 to 2 weeks) on vegetation after treatment are not as spectacular as the desiccating and burning effects of contact herbicides. For this reason, and because of their mode of action, it is difficult to evaluate their initial effects on perennial woody vegetation earlier than 30 days after treatment and their full effects can not be completely evaluated until at least 1 year after treatment.

At rates of application high enough to give contact action, esters of 2,4-D and 2,4,5-T will cause rapid desiccation (5 to 10 days after treatment). Some species will drop their leaves following the use of the phenoxy herbicides in this manner while others will not. The full effects of such treatments in causing desiccation and defoliation and killing vegetation can not be evaluated immediately after treatment.

E. Principles in the Application and Deposit of Phenoxy Herbicides by Aerial Equipment

More than 10 million acres of land, an area half as large as South Vietnam, are treated with the phenoxy herbicides applied by aircraft each year in the United States. Much of the area treated with the phenoxy herbicides in the United States is in range lands, forests,

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rights-of-way, and other non-cultivated areas infested with woody perennial species such as post oak, blackjack oak, shiner oak, mesquite, sagebrush, rabbitbrush, willow, ash, maple and many other species.

Problems encountered in treating lands of this kind are in many respects comparable to those in vegetation control in South Vietnam. The remaining acreage treated by aircraft involves selective weed control in crops.

If the recommendations for the control of woody perennial plants by chemicals applied with aircraft in the United States are summarized, some principles are consistent in the treatments. The herbicides used most widely are the esters of 2,4-D, 2,4,5-T, and mixtures of the two. The rates of application range from 1/3 to 5 pounds acid equivalent per acre (equivalent to about 1/3 pint to 5 pints of "Purple herbicide" per acre). These per acre active ingredient rates are applied in a total volume of 4 to 5 gallons of fuel oil or in an emulsion of one gallon of oil to 2 to 4 gallons of water per acre. Lower per acre volumes of herbicides have been investigated but are not used because of inadequate coverage of dense woody perennial vegetation and too serious drift for maximum effectiveness.

Some principles of spray deposition are outlined on the following page.

SOME PRINCIPLES OF SPERM DEPOSITION

Table 1

Size and Number of Droplets Deposited per Square Inch by Distributing One Gallon of Liquid Uniformly Over a Surface of one Acre

<u>Actual Diameter</u> <u>Microns</u>	<u>Number of Droplets</u> <u>Per Square Inch</u>
50	9,224
100	1,164
200	142
300	42
400	18
500	9

Table 2

The Time Required for Droplets of Various Sizes With a Specific Gravity of 1.0 to Fall 50 Feet in Still Air at 70° F.

<u>Diameter</u> <u>Microns</u>	<u>Time to Fall</u> <u>50 Feet</u>
200	13 seconds
100	51 seconds
50	3.4 minutes

Table 3

The Distances That a Droplet 100 Microns in Diameter With a Specific Gravity of 1.0 Will Drift While Falling 50 Feet in Air Moving Parallel to the Ground.

<u>Wind Velocity</u> <u>Miles Per Hour</u>	<u>Drift Distance</u> <u>Feet</u>
1	87
2	175
3	265
4	348
5	435
10	765

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Using the information in Table 3, a droplet 200 microns in diameter would drift about one-fourth and a 50 mic. droplet about four times the distances given.

The relation of particle size of herbicides and its relation to the application, distribution, and deposit of herbicidal sprays is critically important in achieving maximum effective control of vegetation. If the particle size, especially of volatile herbicides, is too small, drift is serious for two important reasons: (1) the herbicide is not deposited in the intended spray swath and the resulting rate of application may not be adequate for vegetation control and (2) phytotoxic drift particles will injure or kill crop plants and other desirable vegetation outside the intended spray area.

The most effective droplet sizes for the control of vegetation in the United States, using esters of 2,4-D and 2,4,5-T in volumes of 3 to 5 gallons per acre, have ranged from 200 to 500 microns in size, with some smaller and some larger droplets in the spray pattern deposit.

II. Dispersal of Herbicides

A. Methods

Herbicide applications in the United States are made in liquid and granulated form with effective results. The application of herbicides in dust form has been evaluated but has been discontinued because of serious drift problems. The Federal Aviation Agency forbids the aerial application of herbicides in dust form for this reason.

However, when applying liquid herbicides from the air or on the ground consideration must be given to the degree of fineness of the

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spray, as extreme fineness will also create a drift problem as well as reduce the deposit received by the target.

1. Aerial Application

Where application of herbicide sprays is made by aircraft, the general practice in the United States has been to apply the material as a relatively coarse spray. Certain states have established regulations controlling the number of nozzles, orifice size, and operating pump pressure that may be used on aircraft dispersal equipment when applying herbicides. Wind velocity and proximity of susceptible crops are also required considerations for application approval.

To further control drift and increase deposition within the swath, nozzles are positioned to reduce the amount of spray that may be drawn into the vortices formed by the airplane's wingtips. Spray droplets entering the wingtip vortices are raised to greater height than the remainder of the spray not so affected. This increases the time required for the droplets to reach the ground and thereby subjects them to a longer period of drift which may carry them out of the target area.

Spray droplets which drift out of the target area will not be effective in producing the desired vegetation control. This consideration is most important when treating areas which require only one or two spray swaths.

Aerial applications of herbicide sprays are normally made when the air is relatively calm. Wind should not exceed five miles per hour and there should be no thermal activity. However in the treatment

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of large areas where flying can be conducted cross-wind, slightly higher velocities may be tolerated if the wind is steady with no evidence of serious updrafts.

Spray height above the target is usually dictated by the type of aircraft used but should be only as high as is consistent with good swath width and deposit distribution.

2. Ground Application

Herbicides, in spray or granular form, are also effectively applied by several types of ground equipment. Generally, more dilute herbicide sprays are used in ground spraying than are recommended for aerial spraying. Spray volumes are therefore usually somewhat higher than in aerial application, resulting in greater wetting of the vegetation.

Although the nozzles on ground sprayer equipment are usually operated within 20 to 30 inches of the vegetation receiving treatment, drift can be a problem. For this reason it is accepted practice to employ a somewhat larger droplet spectrum size for herbicide spraying than for insecticide spraying.

The application of herbicides by hand or powered ground equipment requires relatively calm wind conditions to permit effective treatment of the vegetation and prevent drift injury to useful vegetation in the immediate vicinity.

B. Equipment

Recommended equipment for the dispersal and application of herbicides in liquid or granular form is generally similar to that for the

application of other liquid or granulated agricultural chemicals. The basic difference in herbicide spray equipment is that larger nozzle orifice sizes and lower pump pressures are used. This produces a spray of larger droplet sizes than would normally be used for insecticide spraying.

Generally spray equipment used for herbicide spraying is not used for the application of other agricultural chemicals because of the extreme difficulty in removing all traces of herbicide from the spray system, even when prescribed cleaning procedures are used.

1. Aircraft

Most aerial applications of herbicides in the United States are made with small airplanes similar to the Piper PA-18A, Piper Pawnee, Grumman Ag-Cat, Snow Ag-Plane, and war surplus Stearman biplanes. These airplanes are capable of carrying 100 to 250 gallons of material. Very few large or multi-engine airplanes have been employed to apply herbicides in the United States to date, although airplanes as large as the B-17, C-46 and C-97 have been used with complete success on large scale aerial insecticide spray programs. Therefore experience in the use of large airplanes for dispersal of herbicide sprays is limited.

Small commercial versions of the Bell and Miller helicopter, capable of carrying approximately 100 gallons are used for herbicide application.

The basic parts required for aerial spraying equipment includes a tank, pump, control valve, and spray nozzles. The nozzles are

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positioned on the aircraft to produce a maximum effective swath. This permits the aircraft to treat as great an area as possible during each spray run.

The number of nozzles, orifice sizes, and pump output capability must be tailored to each size and type of aircraft to deliver the herbicide liquid at the deposit rate desired.

Because most aeri ally applied herbicides are used in the United States at volumes of from 3 to 5 gallons of formulation, containing active ingredients and carriers per acre, the aircraft must be equipped with a pump and plumbing system capable of greater volume than required for most aerial insecticide applications where one gallon per acre is usually adequate.

To provide a coarse spray and reduce drift, a minimum number of high volume nozzles are used. These are usually positioned on a spray boom which may be located under or behind the wing. The nozzles are spaced along the boom to provide an even distribution of spray across the swath. However, the most outboard nozzle on either side is kept well inboard from the wingtip to prevent excess amounts of spray from entering the wingtip vortices. The nozzles are equipped with some type of check valve which provides sharp cut-off of the spray and prevents nozzle dribble.

Dispersal equipment installed in helicopters for herbicide application is usually quite similar to the boom and nozzle equipment used on airplanes.

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The recent acceptance of invert herbicide emulsions for controlling brush along power and pipeline rights-of-way has brought about the development of a horizontal rotating dispersal device especially for use on helicopters.

Granulated herbicides are easily dispersed from aircraft equipped with modern type dusting equipment using a multi-vaned spreader located under the fuselage.

The Swathmaster, manufactured by the Transland Company, is an excellent distributor for granules. It is an airfoil shaped spreader. The upper surface is perforated for release of the material. It can be used to disperse dust, granules or liquids with little or no modification. It was originally designed for use on airplanes similar to the Stearman but is now being used on large twin-engine airplanes such as the North American B-25 and Lockheed PV-2 to apply granulated insecticides on large scale pest control programs.

2. Ground Equipment

The several types of ground sprayers used to apply herbicides employ specially designed herbicide nozzles which produce a coarse, fan-shaped spray, and operate at low pressure. Ground equipment includes boom and nozzle sprayers which may be mounted on a tractor, jeep, or trailer; high clearance, self-powered boom and nozzle sprayers specially built for operation in tall crops and equipped with boom drops to place the nozzles at the recommended spraying height between the row crop for weed control. For roadside spraying of herbicides a special

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adjustable side boom sprayer which mounts on jeeps or trucks is available. A hydraulic sprayer may be used along roadsides or on rights-of-way to reach greater distances across vegetation.

Low volume airblast sprayers may be employed for similar vegetation control where uncontrolled drift of the herbicide would not create a problem. The Buffalo Turbine sprayer is one of this type. Airblast sprayers are available for trailer, tractor, or jeep mounting.

Backpack or shoulder strap carried hand operated sprayers, holding 2 to 5 gallons of liquid are effective herbicide sprayers for all situations where use of larger powered equipment may not be practical. A special herbicide type nozzle is supplied and recommended to provide greater control of the spray droplets.

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PART TWO

EVALUATION OF VEGETATION CONTROL PROGRAM

I. EVALUATION OF VEGETATION CONTROL IN SOUTH VIETNAM

A. Characteristics of the Vegetation

Some understanding of the different kinds of vegetation is necessary for a proper appreciation of the problems of vegetation control in South Vietnam.

Forests occupy a large proportion of the total area of the country. The natural forests have been greatly modified by clearing land for agriculture, and abandoning it after it has been farmed for a time. Such clearing, cultivation, and abandonment gives rise to a secondary forest that differs from the primary forests in some significant characteristics.

Principal Forest Types

The kinds of vegetation of immediate significance from the standpoint of vegetation control are dense evergreen forest, mangrove forest, and tropical scrub. Evergreen forests, as described below, include both primary forests--which have not been cut over--and secondary forests that have re-grown on lands where primary forest has been removed.

Evergreen Forest

In areas which were examined, the evergreen forests were constituted of a "high forest" overstorey having trees up to 90 to 100 feet in total height, and an understorey of small trees, shrubs, and herbs (Fig. 1). Trees of the overstorey are mostly larger than 10 inches in diameter at breast height (4.5 feet above average ground level, abbreviated d.b.h.) or larger. Crowns of overstorey trees usually form two incomplete layers which together may form a very dense canopy and, at other times, may obscure

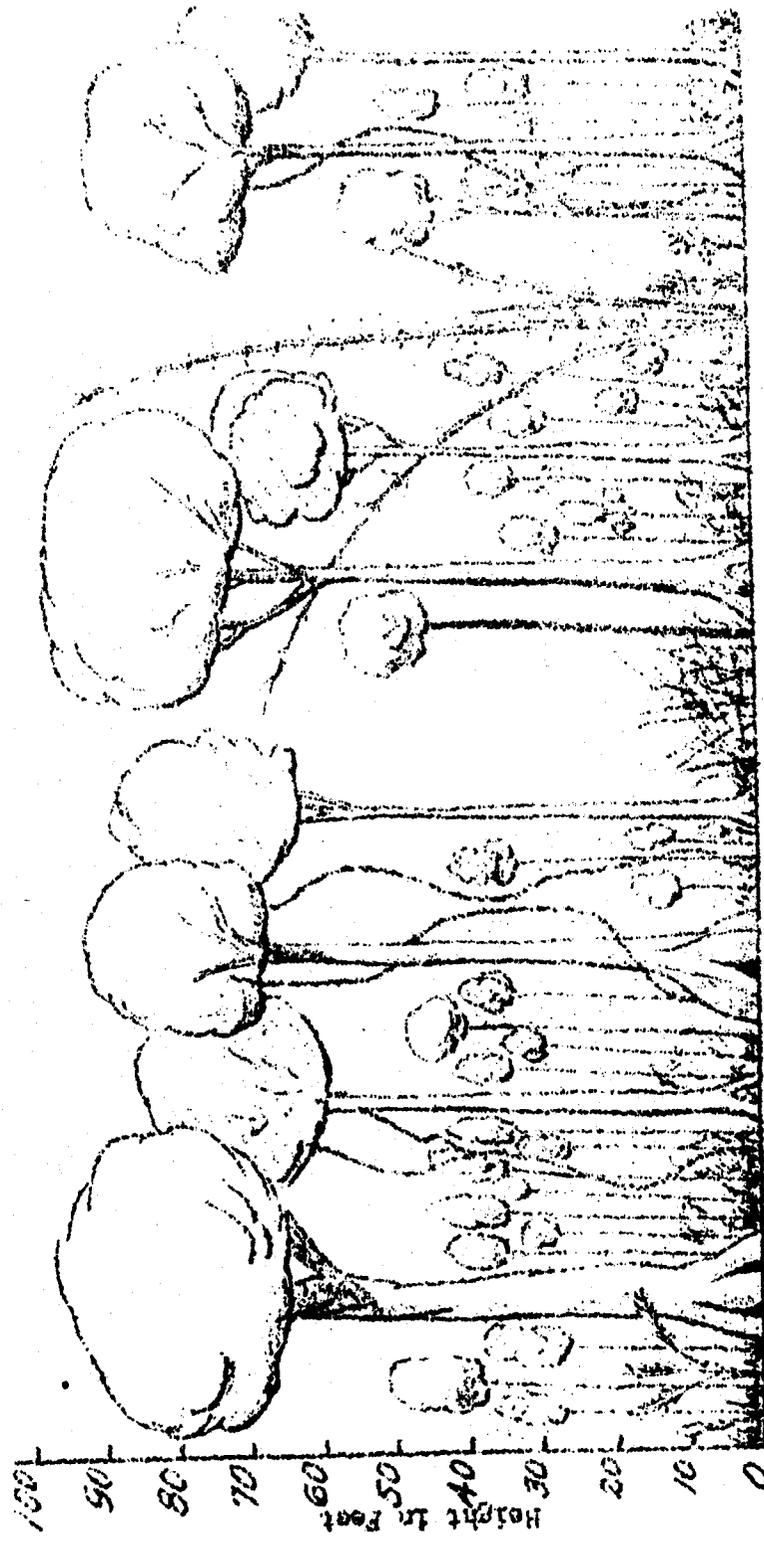


Fig. 1. Profile diagram illustrating the structure of mixed hardwood forests of South West Hill

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NO more than about 20 percent of the ground surface. The lower level of this canopy is at about 50 to 60 feet above the ground. Important among the overstory trees are species of Dalbergia, Calopteryx, Dipterocarpus, Aporosa, Irvingia, Ficus, and some of the giant or tree bamboos. Some of these trees have relatively large buttressed roots, and others have essentially straight trunks. Some lianas (woody vines) reach into the crowns of the overstory trees and are intricately interwoven in the canopy.

The understory is constituted of shrubs, herbs, vines, and small trees. Most of this growth is less than 6 inches in d.b.h., and up to 20 to 30 feet tall. Most of the small trees belong to the understory vegetation, but some are young growth of the overstory species. Bamboos, vines such as lawyer cane and rattan (Calamus spp.), and grasses and other herbs are set closely together in a tangled mass very difficult to travel through, and in which visibility on the ground is limited to a few yards.

A few species of the evergreen forest are deciduous in the dry season, indicating a transition zone to a seasonal evergreen forest. In the areas visited, Peltophorum dasyrachis and Dipterocarpus reticulatus were among the deciduous trees.

Differences between primary and secondary forests are chiefly these: In secondary forests there are fewer large, tall trees and the proportion of shrubs is greater; the understory vegetation is even more dense and difficult to penetrate than in primary forest.

Vegetation of this kind frequently is referred to as "jungle" -- however, jungle is a general term meaning any dense or impenetrable tangle of vegetation.

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Mangrove Forest

In contrast to evergreen forest, the mangrove forest is uniform in structure and composition. Mangroves are of two general kinds: Those that grow in standing water, commonly within the limits of the high tides; and those that grow above tidal limits in marshy to poorly-drained situations. In either case, mangrove tends to form dense, pure stands of even-aged groups of trees; in each group the trees are of about the same size. Height and diameter vary with age, ranging up to from 25 to about 40 or 60 feet for height, and to some 10 inches or larger in d.b.h. The trees are characterized by widely spreading prop roots that impede both movement on the ground and visibility; the crowns form a single layer of nearly continuous canopy that affords almost complete protection from air observation. Typically, herbs or other ground cover is almost absent or entirely lacking, but exceptions do occur; in the vicinity of Hai Yen (Father Hoa's place), there was a ground cover of fern (*Acrostichum*) up to about six feet tall and dense enough to provide nearly complete cover for men.

Tropical Scrub

Of much less importance, but encountered occasionally, are areas of tropical scrub. These are most commonly places where an assortment of shrubs, vines, and grasses have occupied abandoned croplands or similar lands. Frequently bamboo is an important constituent of the vegetation.

The woody vegetation ranges up to about 15 or 20 feet tall--there may be a few scattered small trees that rise above the general level of the other vegetation. The shrubs are characteristically several-stemmed and their crowns are often overrun with vines. Vegetation of this kind affords effective cover and concealment for men, animals, and equipment

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from both air and ground observation. It commonly is extremely difficult to travel through areas of dense tropical scrub.

Important Characteristics in Connection With Vegetation Control

Several features of tropical forest vegetation are in marked contrast to forests of temperate zones. These features may have great significance in connection with vegetation control.

Composition and Structure of the Forests

The number of different kinds of trees is much greater in tropical forests. It is not at all unusual to find several hundred different kinds of plants--trees, shrubs, and herbs--on a single acre of forest in the tropics; thirty to fifty kinds would be more usual in temperate regions. The fact that each kind of plant may differ distinctly in growth responses, in the annual cycle of growth, in tolerance to herbicides, and in other features is of great importance in planning and executing operations for the control of vegetation.

The structure of these forests--that is, the arrangement of the canopy and undergrowth in distinct layers--and the high density of both the individual layers and the total plant cover are important characteristics. Statements were made by Vietnamese scientists and military personnel, having considerable acquaintance with the natural vegetation, that the highest levels of the tree canopy may have shielded the lower level from the herbicides at the rates and times of application. Some evidence tending to confirm these statements was observed in the field work. This possibility should be taken into account in future work and appropriate steps taken to correct it if necessary. Again, according to Vietnamese scientists, the total volume of plant material may be on the order of 300

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metric tons (660,000 pounds) per acre. The leaf surfaces on any given acre may actually total several to many acres in extent. Facts such as these must be recognized and taken into consideration when planning operations and evaluating results.

Annual Cycle of Growth

In lowland areas--below about 3,000 feet--the annual cycle of growth in plants is controlled to a great extent by the wet and dry seasons; but this control is not as rigid as that imposed by the differences between winter and summer in temperate zones. Generally, trees and other vegetation are in a state of active growth during much of the rainy season and are more or less dormant during the dry season. Apparently, a majority of plants begin active growth within a short time of the onset of the rainy season and put on most of their vegetative growth during the early part of it; flower and fruit production would occur later in the season, or possibly near the beginning of the dry season. It appears there may be frequent exceptions to this general statement. The fact that there are significant differences in amounts of rainfall, and in the season of its occurrence from one part of the country to another, can make a great deal of difference in the timing of applications, and in the results obtained. Definitive information is needed on these points, and the advice of local specialists in forestry and agriculture should be sought and utilized. Unless there is a prolonged period of soil moisture shortage -- some 30 days or more -- it is not uncommon for tropical plants to start active vegetative growth at almost any time of year, and it is not unusual for individuals of the same species to begin growth activity at different times of the year. It is possible, also, that in localities

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where there are two peaks of seasonal rainfall, with one or more drier months intervening, there will be two peaks in plant growth activity.

The following information was furnished by the Forestry Director of Research in Saigon in response to specific questions on 20 April 1962:

"1. Does the most active growth period of evergreen forest and tropical scrub generally parallel the rainy season? Answer: Growth period of evergreen forest parallels the rainy season; it begins a little before the start of the rainy season. Growth period of tropical scrub parallels the rainy season; begins with the rainy season; the growth is very strong at the beginning of the rainy season.

"2. What period of the year is the most active growing season for: a. Evergreen forest; b. Tropical scrub? Answer: Period of the most active growing of evergreen forests is April to August. Some species have a second growing period at the end of the rainy season. The period of the most active growing of tropical scrub: Very active from May, and diminishes slowly during the rainy season.

"3. How soon after the rainy season begins before new growth is evident and new leaves are fully expanded and green? Answer: From buds to fully expanded and green leaves - 2 to 3 months. The trees having buds at the beginning of the rainy season have their leaves as soon as some rain has fallen.

"4. What proportion of the species in any single area of evergreen forest are in an active stage of vegetative growth at the same time? The species of the Vietnamese forests vary according to the soils and it would take some time to gather the information to answer this question."

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Generally, plants are most sensitive to herbicides during a period after new growth activity has begun. Because of this direct relationship between growth activity and sensitivity to herbicides, it is necessary that reliable information on local conditions be utilized when planning vegetation control operations. Experienced local specialists should be consulted, and qualified U.S. personnel should be available to interpret, correlate, and disseminate this information to field commands.

Differential Tolerance to Herbicides

During work in this area it was observed that there was a differential tolerance to herbicides among the different kinds of plants. To some extent, this differential tolerance may have been due to differences in stage of growth. Unquestionably, there are other factors involved also.

Among the species identified for us by Vietnamese scientists at several different localities, the relative tolerance to the herbicides used appeared as follows:

<u>Species</u>	<u>Family</u>
<u>Lowest Tolerance to Herbicides</u>	
Grewia paniculata	Tiliaceae
Cratogeomys formosum	Hypericaceae
Dalbergia bariensis	Leguminosae (Papilionaceae)
Pometia pinnata	Sapindaceae
<u>Intermediate Tolerance to Herbicides</u>	
Dipterocarpus intricatus	Dipterocarpaceae
Dillenia ovata	Dilleniaceae
Parinarium annamense	Rosaceae
<u>Highest Tolerance to Herbicides</u>	
Aporosa sphaerosperma	Euphorbiaceae
Sindora cochinchinensis	Leguminosae (Caesalpinaceae)
Popowia aberrans	Anonaceae
Irvingia oliveri	Irvingiaceae
Parinarium sp.	Rosaceae



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Highest Tolerance to Herbicides - continued:

Diospyros lucida	Ebenaceae
Barringtonia	Myrtaceae
Bambusa (bamboos)	Gramineae
Calamus (rattan)	
Acrostichum (fern)	
Grasses and other herbs	

It is not pretended that this is a complete list of species in any of the three categories; it is rather the result of hasty and preliminary observation, in which most attention was directed toward singling out the more tolerant plants, hence more of them are listed. Among these plants the tree Irvingia oliveri appears to be particularly tolerant to herbicides; doubtless, it is only one of several trees that will be found in this category.

It will be necessary to study this matter of differential tolerance to phenoxy herbicides in considerable detail to determine effective procedures for overcoming it in as many plants as possible.

Deciduous Species

While the mixed forests are typically evergreen, some of the trees--Peltophorum dasyrachis; Dipterocarpus Dyeri; D. reticulatus, and doubtless other dipterocarps; and some legumes--are deciduous in the dry season. The proportion of deciduous trees in a given area must be taken into account in assessing the effectiveness of vegetation control measures. In addition, the growth of new leaves on these trees can be readily determined; therefore, their stage of growth may serve as an important indicator of the correct time to apply herbicides to associated trees that do not shed their leaves.

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Plant Succession

When the plant cover is removed from a tract of ground by cutting, burning, or killing it with herbicides, a new cover will grow unless the soil is cultivated or kept open by some other means. This process of cover regrowth follows a series of orderly, more or less predictable steps known as "natural plant succession".

A typical sequence of natural plant succession after complete clearing of overgrown forest in much of Vietnam might be:

1. Grasses or bamboos, or a mixture of the two
2. Dense shrubs
3. Quick-growing softwood trees
4. Slower growing trees; both softwood and hardwood, much like the original forest.

Each of these stages may take from a few to many years; if disturbance is continued, the grass-bamboo or dense shrub stages may persist indefinitely.

Where clearing is not complete, many of the original trees will re-grow from stump sprouts; the result then may very well be a veritable jungle of grasses, bamboos, dense shrubs, and re-growing trees. In other situations, grasses such as blade grass (Imperata cylindrica) and the smaller bamboos (which also are grasses) maintain their hold for very long periods of time and may be quite difficult to control.

The point emphasized here is that some continuing treatment of a maintenance nature will almost certainly be required to keep an area open, once the original vegetation has been removed. It is probable that re-treatment will be required on approximately an annual basis to maintain a cleared condition, but the repeat treatments probably will not require as

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large quantities of herbicide. Plans should be made at the outset to incorporate this maintenance program in the operations planned for any given area.

Disposal of Woody Vegetation by Burning

Herbicides, as employed in military operations under field conditions, are capable of killing most of the kinds of plants growing in the forests of South Vietnam, especially the broad-leaved forms that predominate below about 3,000 feet in elevation. But the dead tree trunks and other vegetation can still provide cover and concealment, and constitute obstacles to observation and movement.

Statements have been made by Vietnamese that local populations will cut and utilize the trees that are suitable for saw timber and that much of the smaller material will be cut and used locally for firewood and charcoal. This utilization should be encouraged to the extent that it furthers military objectives.

There will still remain a large amount of woody material that will interfere with observation and movement. During the team's work here, there has been considerable discussion of the feasibility of disposing of the woody material by burning. Some suggestions for accomplishing this in areas dominated by tropical scrub, where the area is in complete control of friendly populations, are included in Appendix B.

However, the problem of creating sustaining fires in humid tropical regions, even in dead vegetation, is not a simple one. This woody material cannot be readily disposed of without felling the trees and taking other steps to compact the fuels and improve their structure and burning properties. Trees should not be cut for at least sixty days after

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treatment--and preferably on the order of six months--after treatment; otherwise, the herbicides will not have time to exert their full effects. The best technical and professional assistance should be sought. For more than thirty years the U.S. Forest Service and many state forest fire protection agencies have been conducting research on forest fires. This research has included inflammability of fuels, processes of combustion, fire behavior, methods of firing, and many other factors having a direct bearing on the problems of disposal by fire of woody material killed by vegetation control operations. During the last fifteen years a great amount of practical experience has been gained in burning vegetation on wild lands of the American Southwest; in California alone more than one and one-half million acres of land have been cleared by controlled burning of woody vegetation.

The Forest Service is in an excellent position to draw upon this store of fundamental research information and practical experience and to direct and coordinate research in the use of fire for the disposal of this woody material, already having a staff of highly qualified professional personnel and research facilities including indoor and outdoor fire research laboratories. The assistance of this agency should be sought in exploring the feasibility of using fire to dispose of the material killed by vegetation control operations.

B. Herbicides Used for Military Purposes in South Vietnam

<u>Military Code or Trademark</u>	<u>Description of Herbicides</u>
	<u>Chemical Name and Composition</u>
1. Blue	65% cacodylic acid (dimethyarsinic acid) 30% sodium chloride 3% sulfates (as Na_2SO_4) 2% water

2. Blue- 60% T.g. (Technical grade) n-butyl ester of 2,4,5-T
40% T.g. isobutyl ester of 2,4,5-T
3. Green- 95% T.g. n-butyl ester of 2,4,5-T
4. Pink-Green 80% T.g. n-butyl ester of 2,4,5-T
20% T.g. isobutyl ester of 2,4,5-T
5. Dinoxol Commercial formulation of the butoxyethanol esters of a 50-50 mixture of 2,4-D - 2,4,5-T containing 4 pounds of acid equivalent per gallon.
6. Trinoxol Commercial formulation of the butoxyethanol ester of 2,4,5-T containing 4 pounds of acid equivalent per gallon.
7. Purple 50% T.g. n-butyl ester of 2,4-D
30% T.g. n-butyl ester of 2,4,5-T
20% T.g. isobutyl ester of 2,4,5-T

* Pink and Green were procured separately but later mixed to prevent solidification in storage at temperatures below 77°F.

C. Method of Evaluating Targets

During the period 6-18 April 1962, the Evaluation Team inspected from the air and on the ground several research and development, and operational, vegetation targets treated with the butoxyethanol and esters of 2,4-D and 2,4,5-T and one target treated with dimethylarsinic acid. Using a 0 (no effect) to 100 percent (complete effect) scale, each scientist evaluated the targets to estimate: (a) defoliation, (b) canopy kill, (c) vertical visibility, (d) horizontal visibility, and (e) distribution of the herbicide. The detailed data given for each target observation (Appendix A) and in the summary target evaluations (Table 4) are the mean team ratings rounded to the nearest whole number.

Each scientist made written notes of significant observations for use in an analysis of the treated targets. These observations included (a) composition and structure of vegetation, (b) stage of growth of the vegetation, (c) drift of the herbicide and its effects on vegetation outside

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the target area, (d) attempts by the native people to burn the treated areas, (e) cutting of wood in treated areas, and (f) response of vegetation to the herbicides, and other observations.

D. Evaluation of Targets

A thorough and intensive evaluation of eleven (11) targets showed that, when evaluated from the air, the herbicides were approximately 70% effective (range 50 to 90%) in accomplishing the objectives that had been established and, when observed on the ground, they were 60% effective (range 30 to 60%). The evaluation of the targets is summarized in Table 4.

Detailed data on the individual targets evaluated by the team are contained in Appendix A. Location, kind of vegetation, treatment, and other information is presented, in addition to the numerical ratings.

The vegetation responses in areas adjacent to and for two miles downwind from the intended swath deposit indicated that spray drift on most targets resulted in a serious loss of spray deposit from the intended spray swath.

In view of the low volume of Purple dispersed from the aircraft on dormant vegetation and the loss of herbicide as drift and vapors outside the intended spray swath, it is estimated from these considerations and the response of the vegetation that considerably less than one gallon was effectively deposited on the vegetation in the intended spray swath. It is encouraging and critically important to emphasize that even this low amount gave an over-all target effectiveness of 60 to 70%.

It is obvious from the results observed and reported in Table 4 that significant improvements in vegetation control can be expected from

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modifications which will (1) reduce spray drift, (2) increase spray deposit in the intended spray swath, (3) increase the volume and acid equivalent per acre, and (4) apply the herbicide to actively growing rather than dormant vegetation.

The application of the herbicide on the targets was erratic and the distribution poor. Drift of the herbicide outside the targets was serious. The top growth of susceptible trees two miles downwind from the targets had been killed. Circumstantial evidence suggests a critical need for modifications in equipment to produce droplets of greater mass with faster settling rates and less drift potential. The response of evergreen forest to the herbicide strongly indicates a need for better spray coverage and a higher rate of active ingredient per acre.

Some species of woody vegetation were observed enroute to the targets that had shed their leaves in the dry season. The untreated vegetation in the targets was green but there was little or no evidence of new growth. The vegetation appeared dormant even though the leaves were green and little or no natural leaf shedding was observed.

Even though the vegetation was tall--up to 100 feet--seedlings and young trees (1 to 3 feet) under the upper canopy showed epinastic and abnormal growth responses typical of those caused by the phenoxy herbicides. This lower canopy of vegetation obviously had not received an adequate rate of the 2,4-D - 2,4,5-T mixture for maximum effectiveness. In view of the critical limitations in the distribution of the herbicide on the vegetation, the effectiveness of the treatment was surprising.

The upwind sides of targets were clearly defined, but the downwind sides were hardly distinguishable due to serious drift of the herbicide.

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The vegetation on one target was extremely dense. In bright sunlight, an ASA light meter reading of 13 to 25 was recorded in the untreated vegetation, 50 to 150 in treated vegetation, and 300 to 500 in the highway where no vegetation canopy existed. Vietnamese scientists accompanying the evaluation team estimated that one acre of the vegetation would weigh 300 metric tons.

In some of the herbicide-treated areas, natives had started fires. The fires burned the lower canopy vegetation in the treated spray swaths, but the fire went out at the edge of the spray swath and did not burn in the untreated jungle.

Excellent control occurred where adequate quantities of agent were deposited on the plants. Vertical visibility in sprayed areas averaged 80%; while observing one area from an aircraft, VN civilians were spotted in the area prior to a scheduled burning fest.

There has been some regrowth of woody plants two months after treatment with Cacodylic acid. Areas had been prematurely and incompletely burned. There was basal regrowth of some species. There appeared to be good desiccation and top kill of all foliage that was present when the area was treated. The application appeared to be spotty and there were some slipped areas and evidence of drift off the target. Some of the species which were showing some regrowth were identified as Laegstroma lanatoria and Podorrostius. Cassytha filiformis, a dodder-like plant, was also killed by Cacodylic acid. Although Cacodylic acid produces rapid desiccation of foliage, regrowth occurs in many species in approximately 30 to 60 days after treatment. It is, therefore, not recommended for use where permanent vegetation control is desired.

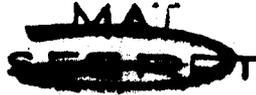


Table 4. Summary of Target Evaluations 1/

Aerial Observations 2/

Evaluation Criteria	Evaluation Av. for Each Target 3/											Evaluation Criteria Av. 3/
	1	2	3	4	5	6	7	8	9	10	11	
1. Defoliation	60	70	80	70	70	70	90	90	90	90	80	80
2. Canopy Kill	60	70	80	60	70	60	90	90	90	80	90	80
3. Vertical Visibility	60	60	80	70	80	60	80	90	90	90	80	80
4. Distribution of Herbicide	30	60	70	40	70	40	80	60	80	70	60	60
5. Total Target Effectiveness	50	70	80	60	70	60	90	80	90	80	80	70

Ground Observations 2/

	1	2	3	4	5	6	7	8	9	10	11	
1. Defoliation	40	2/	70	70	70	50	90	2/	2/	2/	80	70
2. Canopy Kill	40		70	70	80	40	90				80	70
3. Horizontal Visibility	40		50	60	70	40	60				60	50
4. Distribution of Herbicide	10		60	30	80	40	80				60	50
5. Total Target Effectiveness	30		60	60	80	40	80				70	60

NOTES:

- 1/ A rating scale of 0 to 100 percent was used in evaluating the targets. 0 - No effect; 100 - 100 percent effectiveness. Each figure for each target criterion is the mean mean rating. See Appendix A for a detailed description and rating of each target.
- 2/ The targets observed from the air and ground were identical and numbered to permit comparative ratings. All of the eleven (11) target observations were rated from the air; however, target observations 2, 8, 9 and 10 were not rated on the ground.
- 3/ Mean rating values were rounded to the nearest whole number.

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4. Evaluation of Equipment

1. Equipment employed for dispersal of herbicides

The aerial dispersal equipment used in treatment of targets in Task 20 had been hurriedly brought into the area from other parts of the world. None of this equipment was specifically designed for herbicide application or to apply liquids at rates higher than approximately one gallon per acre.

Only a few of the pilots and crew members involved in the operation had had previous experience in aerial application operations of this type. Replacement parts were scarce and personnel experienced in the adjustment and calibration of the dispersal equipment were few.

As a result, little or no modification or adjustments in the equipment was either authorized or undertaken.

Most of the herbicide liquids dispersed in Task 20 had a viscosity equal to No. 20 lubricating oil. This reduced the output capability of the dispersal equipment from that was possible with thinner liquids. This made it necessary to operate the dispersal equipment "full out" and, in some cases, narrow the swath spacing to obtain an application rate of approximately one gallon per acre. It is possible that these limitations in equipment performance may have resulted in something less than the intended treatment on some targets. No detailed records of each mission were kept to show application height, speed, swath width, or calibration information. Some of these details, therefore, were not available.

It is suggested that a detailed record be kept of all pertinent data associated with each flight mission, and that a suitable form be developed for this purpose (see Appendix D).

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The nozzles used on the C-123, C-47, and H-30 dispersal equipment were smaller than is normally recommended for aerial herbicide application. Usually 60 to 200 micron diameter droplets are satisfactory for insecticide applications; however 200 to 400 micron diameter droplets are preferred for aerial application of herbicides.

2. Equipment and method of use

The experimental and operational herbicide applications examined for this report were made by four types of aircraft and one piece of ground equipment.

Fairchild C-123. The Fairchild C-123 airplane is a two engine, high wing monoplane normally used for cargo transportation. The dispersal equipment installed in it is a modified MC-1, "Hour Glass" spray apparatus, originally designed for installation in B-29, B-50 and C-119 airplanes.

The equipment was modified for installation in the C-123 and had been used for dispersal of insecticide sprays. It is composed of a 1,000 gallon aluminum tank, a gasoline engine driven centrifugal pump, and the necessary piping and control valves. These parts are assembled on a single cradle which permits the unit to be easily installed or removed from the airplane.

A two-section boom is located below the wing. Each section extends from just outboard of the engine nacelle to the extreme tip of the wing.

Eighty-four (84) Spraying Systems DL6-45 Teejet nozzles with diaphragm check valves are used, 42 on each boom section. They are directed to the rear and spaced closer on the outer half of each boom section than on the inner half.

The C-123 was flown at ~~approximately~~ 150 mph and between 100 and 150 feet above the target. ~~Swath~~ 1,000 feet. This would require

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an output of 180 gallons per minute to produce an application of one gallon per acre.

Some large areas requiring numerous swaths were treated by two C-123 airplanes flying in formation. The dispersal equipment was operated at the maximum output possible with the number and size of the nozzles installed. This amounted to 127 gallons per mile; a theoretical application of 1.06 gallons per acre. Repeated swath runs would be required to apply two or more gallons per acre.

Suggestions for minor modification of C-123 dispersal equipment

To increase the output of the C-123 dispersal equipment to the maximum without major modification, the following nozzle changes are recommended:

1. Drill and tap additional holes in the inboard section of each wing boom so nozzles can be spaced progressively without omissions.
2. Remove the nut, orifice, whirlplate and screen from the first 35 nozzles on each wing boom, counting from the inboard end, and direct the output of each nozzle downward at 90° to the airstream.
3. Close off all the other nozzles so none will be operating in the vicinity of the wingtips.

It is estimated from preliminary tests conducted on the C-123 with this nozzle modification, using water, that the total maximum output using Purple herbicide will be approximately 180 gallons per minute, or one and one-half gallons per acre over a 400 foot swath at 150 mph. If 3 gallons per acre were required, this would necessitate making two flights over the target.

Major modifications are outlined in Appendix E.

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Paragraph 11. The Douglas C-47, a two engine, low wing airplane, was used only briefly for Round 8 operations and was not available for Round 9 operations. It was equipped with a 675 gallon tank and gasoline-engine-driven Harlow, Model 220 centrifugal pump. The spray boom was in two sections, one under each wing extending from the engine nacelle to the wingtip. Forty-four (44) Spraying Systems 1/8 B-16 whirljet nozzles with diaphragm check valves were used. The dispersal equipment was operated at maximum output which provided an application rate of one half gallon per acre. The C-47 was flown at an air speed of 130 mph and swath spacing of approximately 300 feet. This applied approximately one half gallon per acre. On targets requiring only one swath, the swath was flown twice to apply one gallon per acre.

The two section spray boom installed on the C-123 and C-47 made no provision for locating nozzles in the center one-third of the wing span. This, in effect, produces two separate spray swaths which must meet somewhere behind the airplane before the spray settles. There is a minimum height at which the airplane can be flown with certainty that the separate swaths of spray meet before reaching the target.

Observations made from the air showed evidence in some target areas that the spray from each boom section had not met. This was undoubtedly the result of flying too low.

Moving more nozzles inboard on the boom sections on the C-123 would improve this condition on this airplane and installing a third boom section under the center wing section would greatly improve the C-47 dispersal equipment.

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ment Suggestions for increasing output of Douglas C-47 dispersal equip-

Minor Modification. To improve the effectiveness of the C-47 dispersal equipment without major modification, the 1/2 B-10 nozzles should be removed from the check valve nozzle body and the nozzle output directed downward. As many nozzles should be used as the pump will supply to obtain maximum output from the equipment. It is estimated that approximately 50 nozzle bodies can be used, and the total output will be about 120 gallons per mile.

If the airplane is flown at 150 mph, the effective swath should be approximately 400 feet. A flow rate of 120 gallons per mile will produce an application at one gallon per acre. A second or third run will be necessary to produce an application of 2 or 3 gallons per acre.

Major Modification. A much larger pump, larger plumbing, and greater boom capacity for additional nozzles will be required to apply two or more gallons per acre without repeated spraying. A third boom section should be installed under the center section of the wing to eliminate a light deposit in the center of the swath. See also Appendix E.

Douglas AD-6. The Douglas AD-6 airplane is a single engine fighter of versatile design capable of performing many types of missions. The AD-6 was equipped with an Aero M-3 spray unit, which attached to the underside of the wing. The Aero M-3 holds approximately 90 gallons of spray liquid, which is moved from the tank to the single cone-shaped spray nozzle by pressure valved to the tank from an air storage bottle.

The AD-6 was flown across the target at 204 mph at an altitude above the vegetation of approximately 75 feet - this produced an application rate of approximately two gallons per acre within the swath area.

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Sikorsky H-34. The Sikorsky H-34 is a large single rotor helicopter capable of carrying twelve (12) men.

The dispersal equipment installed in this aircraft is the HHDAL (Helicopter Insecticide Dispersal Apparatus Liquid) developed by the U. S. Navy specifically for this type helicopter. It is composed of a 200 gallon fiberglass tank, an electrically-driven fuel transfer type pump, and a two section spray boom mounted low on the fuselage so it forms a forward pointing Vee.

A total of 40 Spraying Systems U8006 Teejet nozzles with diaphragm check valves are used. The 20 nozzles on each boom section are equally spaced along the boom except for about ten feet on the inboard end where no nozzles are placed. The nozzles are directed downward and produce a flat spray pattern of fine droplet size.

The HHDAL-equipped H-34 helicopter was flown at 55 to 60 mph and at various heights, depending on the dosage specified for the target. The dispersal equipment was operated at the maximum output it was capable of with the number and size of nozzles used. This was approximately 20 gallons per mile.

Suggestions for minor modification of H-34 HHDAL dispersal equipment to increase droplet size and reduce drift

1. Remove the 40 Spraying Systems U8006 Teejet nozzles.
2. Replace with 30 to 35 Spraying Systems DL6-15 Teejet nozzles, similar to those used on the C-122. The total number of nozzles used should be adjusted to the capability of the pump. Since no information on the pump performance was available, it is estimated to be about 30 gallons per minute.

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Buffalo Turbine Sprayer. The Buffalo Turbine Sprayer was used in the treatment of one of the areas observed by the group.

This machine is a trailer-mounted airblast sprayer designed for spraying low volumes of concentrated spray formulations. It is composed of a two-wheel trailer on which is mounted a 100 gallon stainless steel tank and a turbined type blower capable of delivering 14,000 cubic feet of air per minute from the air nozzle. The turbine is driven by a 36 HP, 4-cylinder air-cooled engine. The engine also drives a stainless steel nylon roller type pump, capable of delivering 30 gallons per minute and pressures as high as 150 p.s.i.

Four flooding type hydraulic spray nozzles are positioned in the mouth of the fishtail shaped air nozzle so the spray is well distributed throughout the airblast.

Treatment of approximately six acres of lowwoody growth was made with the Buffalo Turbine Sprayer. The machine was towed back and forth across the area. The air nozzle was directed first to one side of the machine and then to the other so the spray was always directed downwind. Spacing of each swath was controlled to assure good coverage of the vegetation.

Extreme caution is recommended in the use of airblast sprayers for herbicide application because of the air turbulence and uncontrolled drift that may result.

3. Use of MC-1 Assembly for ground sprayer

The MC-1 spray tank and pump assembly could be used for hydraulic spraying of small plots or roadside areas where it might not be safe to use the Buffalo Turbine Sprayer.

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The HC-1 unit could be mounted on an appropriate motor vehicle and equipped with a suitable length of hose and adjustable nozzle spray gun; in fact, several hoses and spray guns could be operated from this unit at one time.

III. HERBICIDES ON HAND IN SOUTH VIETNAM

A. Supply

The following information as to the stock of herbicides on hand in South Vietnam was furnished to the Evaluation Team on 16 April 1962:

Supply of Herbicides Available 16 April 1962

<u>Military Code or Trademark</u>	<u>Drums (50-55 gal. each)</u>	<u>Gallons (approx)</u>
1. Purple	1935	106,425
2. Pink-Green Mixture	1886	103,730
3. Pink	None	None
4. Green	None	None
5. Dinocrol	Small Quantity	Unknown
6. Trinocrol	Small Quantity	Unknown
7. Blue	132 (100 lb. cartons)	13,200 lb.

B. Storage Condition of Herbicides

The Evaluation Team inspected the herbicide storage depot 16 April 1962, and the condition of the drums and method of storage were generally satisfactory. Except for the "Blue" herbicide, all drums were stored in the open unsheltered enclosure of the depot. The drums were stored for efficient identification, loading and storage. Several drums had developed minor leaks due to damage in transit. The vegetation inside the depot was already dead or dying and the vegetation immediately adjacent to the depot was showing severe injury. This injury was due to volatilization during mixing operations in the depot and to leakage from the drums.

C. Herbicide identification and compliance with composition specifications

The drums were identified by a four-inch-wide band of purple, pink, green, or blue paint, depending on the herbicide present, around the center

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of each drum. Under conditions of outside storage in high light intensities, these color bands have faded and are becoming difficult to distinguish. Better methods of identifying future stocks are needed.

The Purple herbicide from a single C-123 aircraft tank load (1000 gallons) was examined. The herbicide possessed a dark brown color with a viscosity estimated to be similar to that of SAE20 motor oil. Only the Purple and Blue herbicides have been used on an operational basis in South Vietnam. Personnel responsible for the application of herbicides in the operational program indicated that no difficulties had been encountered in the physical properties of the Purple herbicide. They had not encountered any solidification or precipitation with Purple. Earlier in the program, the Green had solidified, but this difficulty was corrected by mixing it with Pink and no further solidification or other difficulties occurred.

The Purple herbicide contained 20 percent technical grade (T.g.) isobutyl ester of 2,4,5-T to prevent solidification of the n-butyl ester of 2,4,5-T at temperatures below 77°F. Information available to procurement personnel from the manufacturer indicates that the isobutyl ester of 2,4,5-T is equally as phytotoxic as the n-butyl ester of 2,4,5-T. The accuracy of this information has not been questioned or confirmed by the procuring agency.

The team requested data from analytical tests to determine whether the herbicides delivered by the manufacturers complied with the specifications of the procuring agency. No analytical tests had been conducted to check compliance with the specifications and such information was not available. Statistical sampling and analytical tests should be conducted on present and future stocks to assure compliance with procurement specifications.

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PART THREE:

CONCLUSIONS AND RECOMMENDATIONS

I. Conclusions

The results of the team's evaluation of the effectiveness of herbicides in controlling vegetation in South Vietnam strongly support the following conclusions:

1. Evidence examined and evaluated shows conclusively that if properly applied at suitable rates with proper equipment, herbicides unquestionably can be used to control vegetation. The operational program of vegetation control should be continued, provided the modifications in techniques and equipment recommended by the technical evaluation team are made.

2. A thorough and intensive evaluation of twenty-one targets in eleven observational areas showed that when evaluated from the air, the herbicides were approximately seventy per cent effective in accomplishing the objectives that had been established; and when evaluated on the ground they were sixty per cent effective. Based on research results and use in the United States, and limited employment in South Vietnam, when properly used these herbicides can produce very significant results in twenty to sixty days, depending on the kind of vegetation.

3. One of the most important limiting factors in reducing effectiveness in achieving the full objectives of the research and operational programs was the dispersal equipment. This equipment was designed to

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deliver approximately one gallon per acre of liquids with viscosity similar to fuel oil, in fine droplets. This volume of one gallon per acre, in fine droplets, did not result in an adequate deposit of herbicide of the viscosity used, for optimum control of all types of mixed tropical vegetation in South Vietnam. Therefore modification of the equipment will be required. All aircraft used are suitable for herbicide application if equipped with adequate dispersal equipment. Fine spray droplets and poor nozzle arrangement on the aircraft resulted in excessive loss of the herbicides by drift.

4. Another very important limiting factor in controlling the vegetation was that in some cases the herbicides were applied during the period when the plants were dormant.

5. Plants differ in their tolerance to herbicides and these differences must be taken into account in planning vegetation control and evaluating effects of herbicides. Since systemic herbicides, such as Purple, continue to exert their effects over a long period of time, evaluation cannot be made within a short time after application. Initial evaluation should not be made in less than thirty days and final evaluation in less than one year after treatment.

6. The amount of Purple used per acre gave excellent control of mangrove, but the active ingredients and volume applied per acre were not adequate to give maximum effectiveness in killing evergreen forest and tropical scrub when dormant. When properly employed, herbicides are capable of killing most plant species encountered in the forests of

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Vietnam, but the dead trunks and other vegetation still remain and impair visibility. It may be feasible to develop effective techniques for improving the fuel structure so the woody material can be disposed of by burning or other means.

7. Additional basic information is needed on herbicides, equipment, and vegetation to improve the effectiveness of vegetation control and develop an operational capability in tropical regions. The conditions prevailing in South Vietnam preclude the conduct of an effective research program which is critically needed. Results achieved in vegetation control and problems encountered in South Vietnam demonstrate conclusively that an intensive program of research must be initiated without delay in localities where there is ready access to the experimental areas.

8. The Evaluation Team did not see or examine any areas where food plants had been treated with herbicides. Based on extensive research conducted in the United States and in many tropical and non-tropical countries, the technical feasibility of killing all crops in South Vietnam with herbicides at any time during their life cycle prior to the production of edible portions is well established. The herbicides necessary are now in military stocks. However, other herbicides are available commercially with which crops in selected areas can be killed without damage to crops of the same kind in nearby areas.

II. Recommendations

The Evaluation Team makes the following recommendations with respect to:

- A. An operational program of vegetation control --

1. It is strongly recommended that the operational phase of the vegetation control program in South Vietnam be resumed immediately, provided:

a. That minor modifications on the MC-1 dispersal equipment on the C-123 aircraft and the dispersal equipment of all other operational aircraft be changed immediately to deliver a volume of approximately one and one half (1 1/2) gallons per acre of Purple, in accordance with suggested modifications in this report.

b. That the aircraft which is delivering 1 1/2 gallons per acre make two passes on each target by applying one-half the load and immediately respraying the same swath with the second half of the load, in order to deliver a total volume of 3 gallons per acre on the vegetation.

c. That the dispersal equipment nozzles be modified to deliver droplets of approximately 300 micron size.

2. That as soon as possible a team of three specialists be obtained from the United States to provide technical assistance to the operational program:

- a. Chemical weed and vegetation control specialist
- b. Agricultural aircraft spray equipment specialist
- c. Tropical vegetation specialist

3. That a complete "target analysis" of each area to be treated be made with the assistance of the qualified specialists to determine:

- a. Stage of growth and kind of vegetation.
- b. Selection of herbicide.
- c. Rate of herbicide active ingredients and total volume of spray per acre.

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d. The susceptibility of and hazard to adjacent crops and desirable vegetation.

e. Selection of appropriate dispersal equipment.

f. Meteorological conditions, including atmospheric stability.

h. It is strongly recommended that vegetation be treated with herbicides during its period of active growth.

a. Evergreen forest and tropical scrub should be treated when they are actively growing. The period of active growth generally coincides with the rainy season. It is pointed out that the rainy season occurs at different times of the year in different parts of South Vietnam.

b. However, available information indicates that mangrove forest may be treated with herbicides at any time regardless of growing season.

5. Small plots, roadside areas, rights-of-way, and similar areas should be treated with ground type equipment utilizing the information given in this report.

6. That, to afford adequate opportunity for the systemic herbicides employed to exert their full effect, no cutting or burning of treated vegetation be permitted for at least sixty (60) days, and preferably for as long as six months.

7. That, where it is necessary to maintain areas free of vegetation on a permanent basis, a maintenance program be carried out. The need for repeat treatments can be determined only by inspection and knowledge of local requirements.

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a. It is probable that, if Purple is used, retreatment will be required on approximately an annual basis.

b. It is probable that the amount of herbicide required for repeat treatments will be less than required in the original.

8. That stocks of Purple and mixed Pink and Green herbicides on hand be sampled according to statistically sound methods, and the samples sent to the United States for analysis to determine the identity of the esters, the amount of each, and the total acid equivalent of 2,4-D and 2,4,5-T present per gallon.

9. That it is technically feasible to kill all of the various kinds of crops in South Vietnam with herbicides now in military stocks (Appendix C). However, other herbicides are available commercially with which crops in selected areas can be killed in South Vietnam without damage to crops of the same kind in nearby areas.

B. A program of Research and Development in vegetation control

1. That an accelerated Research and Development Program in vegetation control be initiated in the United States and Thailand to investigate the following:

- a. Effectiveness of selected herbicides.
- b. Effects of surfactants (surface active agents) such as soaps, detergents, emulsifiers, stickers and wetting agents.
- c. Development of improved dispersal equipment for aerial and ground operations.
- d. Determination of optimum rates of active ingredients, volume, and droplet size for maximum deposit and effectiveness of herbicides and mixtures on tropical vegetation.



o. Annual cycle of growth and other ecological characteristics of tropical vegetation, especially tropical forests.

1. Feasibility of developing effective methods of using fire and other means to dispose of woody material killed by vegetation control operations.

g. Develop an aircraft dispersal system capable of delivering 3 gallons of spray volume per acre as soon as possible.

2. The research program recommended involves many aspects of the agricultural and biological sciences. Therefore, it should be planned and carried out with consultation and cooperation of governmental agencies, educational institutions, and others qualified in the agricultural and biological sciences to utilize the research information and experience of such agencies to provide mutual benefits.

3. That, prior to operational use, the final field testing of equipment, herbicides, and techniques developed in the United States and Thailand Research and Development Programs be accomplished in South Vietnam.

4. That investigations be conducted on dispersing systems for herbicides in solid, liquid, or vapor form for use in attacking small plantings of food crops.

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Appendix A: Target Evaluation Data

To Report

REVIEW AND EVALUATION of ARPA/OSD "DEFOLIATION" PROGRAM
in SOUTH VIETNAM

Research Phase: 15 July 1961 -- 12 January 1962

Operational Phase: 13 January 1962 -- March 1962

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TARGET EVALUATION

A. TARGET DESCRIPTION:

1. Observation No. 1
2. Target Location: Chon-Thanh XT 770580 - XT 790550
Route or Village Sheet #211-W (Hon-Quan)
Map Coordinates
3. Type of vegetation and condition of growth:
Evergreen Forest; dormant; a few species are deciduous in the dry season.
4. Herbicide and rate of treatment per acre:
Butoxyethanol esters of 2,4-D and 2,4,5-T (Dinocol) 1/2 lb. ai/gal); 1 gallon of formulation per acre.
5. Date and time of treatment:
24 August 1961; 1000 hours.
6. Weather conditions at time of treatment: Unknown.
7. Equipment used in making treatment: C-47 aircraft.

B. TARGET EVALUATION:

Evaluation Criteria	Evaluation Average	
	Aerial Rating	Ground Rating
1. Defoliation	60	40
2. Canopy Kill	60	40
3. Visibility:		
Horizontal		40
Vertical	60	
4. Distribution of herbicide	30	10
5. Total Target Effectiveness	50	30

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TARGET EVALUATION

A. TARGET DESCRIPTION:

1. Observation No.: 2
2. Target Location: Highway 1, Dong-Koad YT 060757 - YT 160835
Route or Village Sheet #211-E (Hon-Quan)
Map Coordinates
3. Type of vegetation and condition of growth:
 Evergreen Forest; dormant; a few species are deciduous in the dry season.
4. Herbicide and rate of treatment per acre:
 Undiluted butyl esters of 2,4-D and 2,4,5-T (Purple)
 1 gallon per acre.
5. Date and time of treatment:
 February 1962; 0600-0800 hours.
6. Weather conditions at time of treatment: Unknown.
7. Equipment used in making treatment: C-123 aircraft.

B. TARGET EVALUATION:

Evaluation Criteria	<u>Evaluation Average</u> <u>Aerial Rating</u>
1. Defoliation	70
2. Canopy Kill	70
3. Visibility:	
Horizontal	
Vertical	60
4. Distribution of herbicide	60
5. Total Target Effectiveness	70

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TARGET EVALUATION

A. TARGET DESCRIPTION:

1. Observation No.: 3
2. Target Location: Route 1, Chua Chan YT 685023 - XS 765985
Route or Village Sheet #222-W (Gia-Ray)
Map Coordinates
3. Type of vegetation and condition of growth:
Evergreen Forest; dormant.
4. Herbicide and rate of treatment per acre:
Purple - 1 gallon per acre.
5. Date and time of treatment:
February 1962; 0600-0800 hours.
6. Weather conditions at time of treatment: Unknown.
7. Equipment used in making treatment: C-123 aircraft.

B. TARGET EVALUATION:

Evaluation Criteria	Evaluation Average	
	Aerial Rating	Ground Rating
1. Defoliation	80	70
2. Canopy Kill	80	70
3. Visibility:		
Horizontal		50
Vertical	80	
4. Distribution of herbicide	70	60
5. Total Target Effectiveness	80	60



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TARGET EVALUATION

A. TARGET DESCRIPTION:

1. Description No.: 4
2. Target Location: Bien-Hoa (Tan-Phong) IT 995115
Route or Village Sheet #201-N (Saigon)
Map Coordinates
3. Type of vegetation and condition of growth:
Scrub; dormant.
4. Herbicide and rate of treatment per acre:
Butoxyethanol ester of 2,4,5-T (Trioxetol) 4 lb/al/acre
1 gallon per acre. Resprayed with Purple.
5. Date and time of treatment:
October 1961. Resprayed March 1962.
6. Weather conditions at time of treatment: Unknown.
7. Equipment used in making treatment: C-47 aircraft
H-34 helicopter

B. TARGET EVALUATION:

Evaluation Criteria	Evaluation Average	
	Aerial Rating	Ground Rating
1. Defoliation	70	70
2. Canopy Kill	60	70
3. Visibility:		
Horizontal		60
Vertical	70	
4. Distribution of herbicide	40	30
5. Total Target Effectiveness	60	60

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TARGET EVALUATION

TARGET DESCRIPTION:

1. Observation No.: 5
2. Target Location: Rien-Hoa XT 978147
Route or Village Sheet #221-11 (Saigon)
Map Coordinates
3. Type of vegetation and condition of growth:
 Herbs; dormant.
4. Herbicide and rate of treatment per acre:
 Dismethylandic acid (Cacodylic acid) 3 lb/acre
5. Date and time of treatment:
 February 1968; 1000 hours.
6. Weather conditions at time of treatment: Unknown.
7. Equipment used in making treatment: Buffalo Turbine airblast
 ground sprayer

B. TARGET EVALUATION:

Evaluation Criteria	Evaluation Average	
	Aerial Rating	Ground Rating
1. Defoliation	70	70
2. Canopy Kill	70	80
3. Visibility:		
Horizontal		
Vertical	80	70
4. Distribution of herbicide	70	80
5. Total Target Effectiveness	70	80

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TARGET EVALUATION

I. TARGET DESCRIPTION:

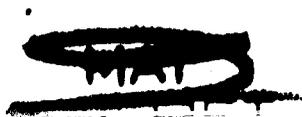
1. Observation No. 61/
2. Target Location: Route 151/
Route or Village _____ Map Coordinates 1/
3. Type of vegetation and condition of growth:
Evergreen Forest; scrub.
4. Herbicide and rate of treatment per acre:
Purple, 1 gallon per acre.
5. Date and time of treatment:
January 1962; 0700 hours.
6. Weather conditions at time of treatment: Unknown.
7. Equipment used in making treatment: C-123 aircraft.

II. TARGET EVALUATION:

Evaluation Criteria	Evaluation Average	
	Aerial Rating	Ground Rating
1. Defoliation	70	50
2. Canopy Kill	60	40
3. Visibility:		
Horizontal		40
Vertical	60	
4. Distribution of herbicide	40	40
5. Total Target Effectiveness	60	40

NOTE: 1/ About 15 individual targets along Route 15 identified by the following map coordinates:

5/1 YT 072063	5/7 YS 213813	5/13 YS 386558
5/2 YT 082011	5/8 YS 240770	5/14 YS 245710
5/3 YT 100621	5/9 YS 255710	5/15 YS 365535
5/4 YT 103016	5/10 YS 276652	Sheet #221-E (Saigon)
5/5 YS 112995	5/11 YS 380585	Sheet #230-E (Cholon)
5/6 YS 217825	5/12 YS 378565	



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TARGET EVALUATION

I. TARGET DESCRIPTION:

1. Observation No.: 7 5/12 YS 378565
2. Target Location: Route 15 Sheet #221-E (Saigon) -
Route or Village Sheet #230-E (Cholon)
Map Coordinates
3. Type of vegetation and condition of growth:
Mangrove.
4. Herbicide and rate of treatment per acre:
Atrazine, 1 gallon per acre.
5. Date and time of treatment:
January 1962; 0700 hours.
6. Weather conditions at time of treatment: Unknown.
7. Equipment used in making treatment: C-123 aircraft.

II. TARGET EVALUATION:

Evaluation Criteria	Aerial	Evaluation Average	
		Rating	Ground Rating
1. Defoliation	90		90
2. Canopy Kill	90		90
3. Visibility:			
Horizontal			60
Vertical	80		
4. Distribution of herbicide	80		80
5. Total Target Effectiveness	90		80

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TARGET EVALUATION

A. TARGET DESCRIPTION:

1. Observation No.: 8 K/15 YS 365535
2. Target Location: Route 15 Sheet #221-E (Saigon) -
Route or Village Sheet #230-E (Cholon)
Map Coordinates
3. Type of vegetation and condition of growth:
 Man rove, semi-dormant.
4. Herbicide and rate of treatment per acre:
 Purple, 1 gallon per acre.
5. Date and time of treatment:
 January 1968
6. Weather conditions at time of treatment: Unknown.
7. Equipment used in making treatment: C-123 aircraft

B. TARGET EVALUATION:

Evaluation Criteria	<u>Evaluation Average</u> <u>Aerial Rating</u>
1. Defoliation	90
2. Canopy Kill	90
3. Visibility:	
Horizontal	
Vertical	90
4. Distribution of herbicide	60
5. Total Target Effectiveness	80



TARGET EVALUATION

A. TARGET DESCRIPTION:

1. Observation No.: 9
2. Target Location: Song Ong Doc, Hai Yen VR 820050
Route or Village Sheet #241 (Ca-Hau)
 Map Coordinates
3. Type of vegetation and condition of growth:
Mangrove, semi-dormant.
4. Herbicide and rate of treatment per acre:
Purple, 1 gallon per acre.
5. Date and time of treatment:
17 February 1962; 0600-0800 hours.
6. Weather conditions at time of treatment: Unknown.
7. Equipment used to make treatment: C-123 aircraft.

B. TARGET EVALUATION:

Evaluation Criteria	<u>Evaluation Average</u> <u>Aerial Rating</u>
1. Defoliation	90
2. Canopy Kill	90
3. Visibility:	
Horizontal	
Vertical	90
4. Distribution of herbicide	80
5. Total Target Effectiveness	90



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TARGET EVALUATION

A. TARGET DESCRIPTION:

1. Observation No.: 10
2. Target Location: Pathet Hoa, Hai Yen Sheet #244-N (Ponte de Ca-Mau)
Route or Village Map Coordinates
3. Type of vegetation and condition of growth:
Mangrove, semi-dormant.
4. Herbicide and rate of treatment per acre:
Purple, 1 gallon per acre.
5. Date and time of treatment:
16 February 1962; 0600-0800 hours.
6. Weather conditions at time of treatment: Unknown.
7. Equipment used to make treatment: C-123 aircraft

B. TARGET EVALUATION:

Evaluation Criteria	<u>Evaluation Average</u> <u>Aerial Rating</u>
1. Defoliation	90
2. Canopy Kill	80
3. Visibility:	
Horizontal	
Vertical	90
4. Distribution of herbicide	70
5. Total Target Effectiveness	80

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Appendix B: The Control of Vegetation Around
Military Installations in Vietnam

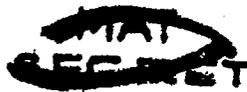
To Report

REVIEW AND EVALUATION OF ANPA/OSI "DEPOLIATION" PROGRAM
in SOUTH VIETNAM

Research Phase: 15 July 1961 -- 12 January 1962

Operational Phase: 13 January 1962 -- March 1962

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APPENDIX B

THE CONTROL OF VEGETATION AROUND MILITARY INSTALLATIONS IN VIETNAM

The following program is recommended:

1. At the beginning of the rainy season after new growth is apparent, apply three (3) gallons of Purple per acre as a foliage spray using aerial equipment.

2. In the first dry season after purple has been applied, when the foliage is dead and the twigs and branches are dry, the woody vegetation should be crushed to compact the fuel and improve its structure for burning. Crushing may be done by any one of several methods:

a. Use a heavy caterpillar-type tractor (D-7) with bulldozer blade. Drive the tractor back and forth over area with the bulldozer blade raised approximately one foot above the ground surface (Fig. 1). Height of blade should be adjusted so that shrubs will be pushed over or broken off; but it should not be kept so low that the blade picks up soil, or so that the woody material will "ball" or roll in front of it. The purpose is to compact the fuel into a uniform layer, evenly distributed over the surface.

b. A heavy chain - such as an anchor chain - may be dragged over the area, using two tractors (Fig. 2). This is merely an extension of paragraph a, above, to do the crushing at a faster rate.

The chain should weigh at least 60 to 70 pounds per foot; if a single chain is not heavy enough, two lengths of chain should be used.

About 80 to 100 feet of chain are required. As the chain will roll in use, a swivel should be placed in the middle, and one at each end to prevent sinking and knotting. A length of heavy wire rope (about 3/4" to 1") connects each end of the anchor chain to a swivel attached to the tractor (Fig. 2).

In operation, the tractors should be driven abreast, close enough together so that the chain will form a loop. One pass over the area should be sufficient but, if the compaction is not believed adequate, a second pass may be made in the opposite direction.

After crushing, the woody vegetation should be allowed to dry for as long as is feasible; one week certainly, and for as long as a month or two if but little rain occurs.

Before burning, a firebreak about 30 to 50 feet wide should be prepared around the entire perimeter, by scraping soil down to subsoil earth with a bulldozer. All dry woody material should be pushed well into the area to be burned - it should not be piled outside the area to be burned.

The burning should be executed in at least two steps (Fig. 3).

- (1) Fire the edge away from the prevailing wind;
- (2) Then fire the adjoining two edges and the windward side.



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Additional firing in the interior may be done. It MUST be done as the sides are fired, and the persons working nearest the center must keep ahead of those to the sides; otherwise, personnel will be trapped in the flames.

A back-firing torch, or drip torch, such as that used by the U.S. Forest Service and various state forest fire protection agencies, is a suitable piece of equipment for igniting material of the kind to be burned here. (The Western Fire Equipment Company, San Francisco, California, is one source of supply.)

Caution:

All interior firing must be done into the wind. If firing is done with the wind behind personnel doing the firing, the flames can travel faster than a man can walk, and personnel are likely to be trapped and burned.

Burning by this method should remove 80 to 90 percent of the woody material; without preparation, clearing more than 40 percent of it would be fortunate.

(3) Just prior to the beginning of the following rainy season and after burning, apply a 50 percent granular formulation of monuron (Karnex DW)* at the rate of 40 pounds per acre using a 20 foot Gandy Spreader pulled by a jeep or other suitable equipment.

(4) At the beginning of each subsequent rainy season, apply 20 pounds of a 50 percent granular formulation of monuron (Karnex DW) per acre.

(5) For the control of spot infestations of vegetation around obstructions that were not controlled by aerial or ground equipment application, apply a broadcast treatment of granular monuron by hand or hand operated applicator.

NOTE:

* Source: E. I. du Pont de Nemours and Company, Wilmington 28, Delaware, U.S.A.

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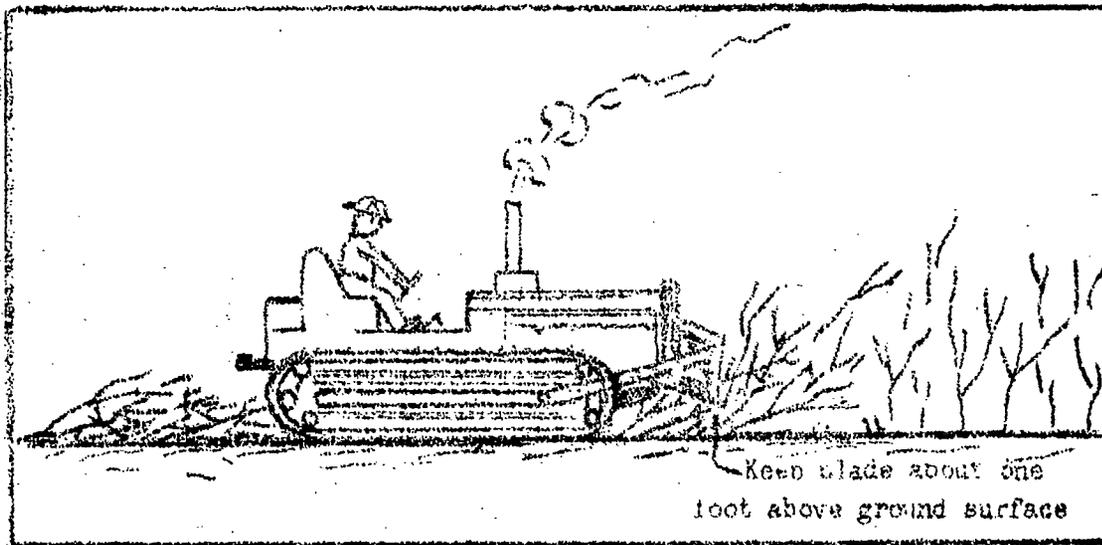


Fig. 1. Method of compacting shrubby vegetation for burning, by crushing with bulldozer blade.

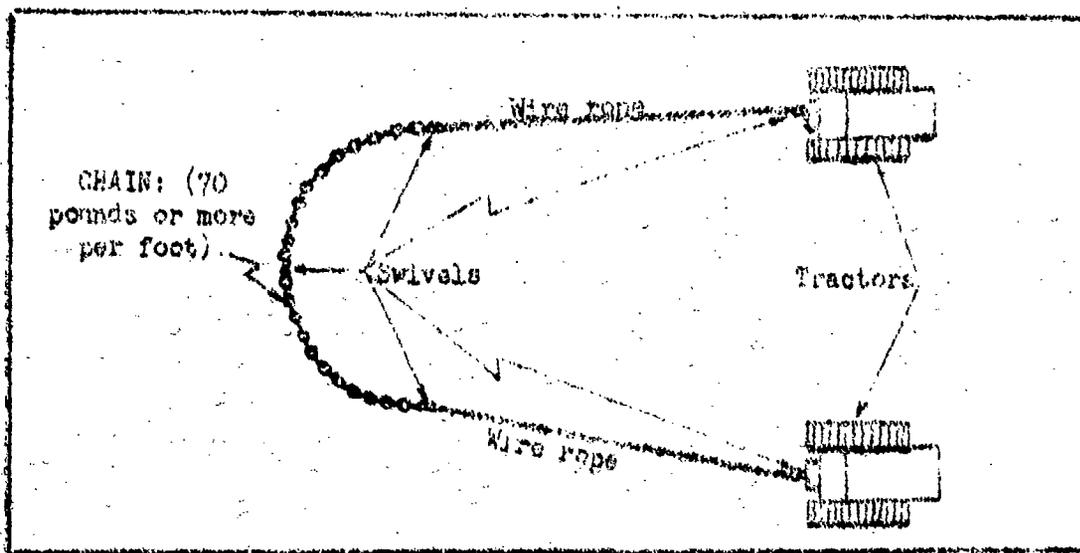
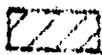
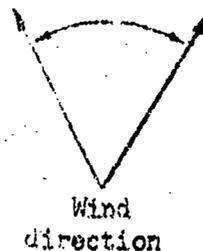
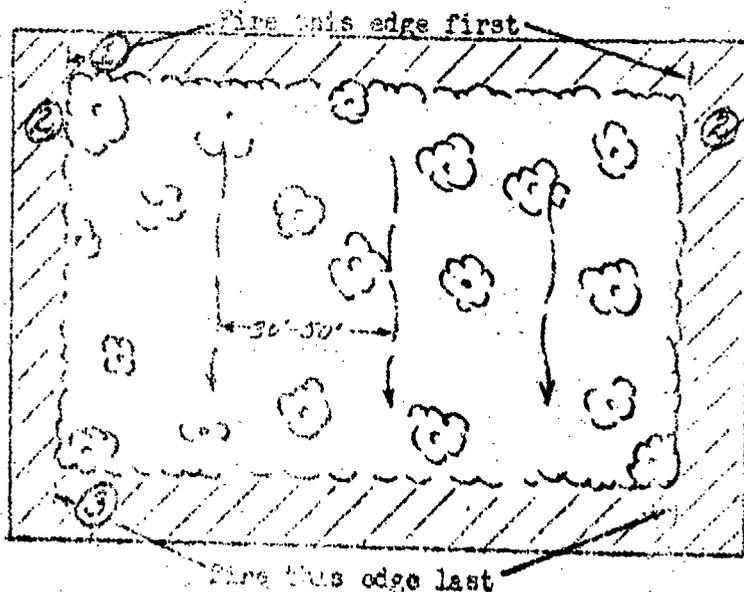
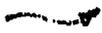


Fig. 2. Compacting shrubby vegetation for burning, by crushing with anchor chain pulled by two tractors.



Cleared firebreak



Sequence firing. Additional firing may be done along lines 30 to 50 feet apart. Firing must be done here as sides are fired, and personnel must keep in advance of those on sides.



Sequence of firing edges

Note: If wind direction differs from that indicated, shift sequence of firing edges accordingly--first edge fired should be against the wind.

Fig. 3. Firing plan for burning shrubby vegetation that has been crushed and allowed to dry.

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Appendix C: Destruction of Viet Cong Crops With Chemicals

To Report

REVIEW AND EVALUATION of ARPA/OSD "DEFOLIATION" PROGRAM
in SOUTH VIETNAM

Research Phase: 15 July 1961 -- 12 January 1962

Operational Phase: 13 January 1962 -- March 1962

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APPENDIX C

DESTRUCTION OF VIET CONG CROPS WITH CHEMICALS

I. Objective

To recommend agents, disseminating equipment, methods of employment and other pertinent information relating to the destruction of Viet Cong (V.C.) crops.

II. Target Crops

The principal food crops on which the Viet Cong subsist and which the team has been asked to consider as target crops are rice, manioc, sweet potatoes, and corn. Two of these crops, sweet potato and manioc, are broadleaved and produce edible roots. Both are very susceptible to the 2,4-D - 2,4,5-T type herbicides. The other two, corn and rice, are narrow leaf plants which are also susceptible to the same type of herbicides but require heavier doses. In addition rice is very susceptible to relatively low rates of cacodylic acid.

III. Herbicides

The agents currently on hand in Vietnam namely a mixture of the butyl and isobutyl esters of 2,4-D and 2,4,5-T (Purple), the mixture of normal butyl and isobutyl esters of 2,4,5-T (Green and Pink) and cacodylic acid (Blue) are admirably suited for destroying the target crops.

If all four target crops are growing in the same or adjacent fields and are to be sprayed simultaneously by an aircraft spray mission, Purple should be used and the dosage should be adjusted to that required for the most resistant crop.

In spraying small areas with hand sprayers similar to the 3 gallon garden type knapsack sprayer, the dosage should conform to the requirements of the specific crop being sprayed even though several different crops are present in the same field.

The dosage required depends on the age of the plant and its stage of growth. Plants in general are most susceptible during periods of rapid growth such as during the young seedling stage and in some species during the early reproductive stages.

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Low dosages of Purple will kill young sweet potato plants (3 weeks old) but dosages equivalent to about 1 gallon of Purple should be used to kill plants regardless of age to obviate mistakes in estimating plant age and to provide an adequate safety factor. The gallon of Purple should be dissolved in 2 gallons of fuel oil to yield 3 gallons of spray solution.

Rice and corn can be killed by approximately $\frac{1}{2}$ gallon per acre of Purple when young but 10 lbs. or 1.0 gallon may be required for older plants. However if rice and corn are sprayed during the early reproductive stage they can be rendered unproductive with 0.1 gallon of Purple per acre. Since it is impossible to determine the exact stage of development accurately as a plant approaches maturity without detailed observation of the crop on the ground, it is recommended that no attempt be made to confine the attack to low doses during the early reproductive stages.

Where the target crop is rice and no other crops are involved, cacodylic acid (Blue) could be used. This herbicide is effective in killing rice or rendering it unproductive at application rates of approximately one pound per acre during approximately 90 days of its growth cycle. However to insure more positive results 7 pounds per acre of Blue should be employed operationally. This should be contained in 3 gallons of spray solution (2.3 lbs. blue/gallon of water).

Cacodylic is corrosive to aluminum and brass and caution must therefore be exercised in selecting the proper spray equipment.

When stocks of Purple, Green, and Pink become exhausted consideration should be given to the procurement of low-volatile esters of 2,4-D and 2,4,5-T for use on broadleaf crops. The use of low-volatile esters will minimize losses due to volatility from small targets and possible damage to nearby crops not intended for destruction.

IV. Disseminating Equipment

A number of disseminating systems that have been used in Vietnam could be modified for use in attacking crops. These are:

H-34	with	HIDAL
C-123	with	MC-1
C-47	with	Insecticide spray equipment
AD6	with	Aero 14B

An additional item is the 3 gallon knapsack sprayer.

The spray volume required for crop sprays is 3 gallons per acre and the droplet size should be at least 300 microns. All of the above items of equipment require modification to permit the desired flow rates and droplet size.

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The H-34 with HIDAL appears to be suitable for attacking target areas of 1 to 100 acres in size. However, if the area is not secured by ground troops or by fighter air cover a serious hazard from enemy ground fire could exist.

The C-123 with MC-1 spray system is unsuitable for crop sprays except for very large targets. It is doubtful that crop targets of sufficient size exist to warrant use of such a large spray system.

The AD6 with two wing mounted Acre 14B's appears to be the most suitable system for spraying small targets in enemy controlled territory. Its relatively high speed would permit it to get in and out of target areas rapidly and its two 14B spray devices each capable of carrying 90 gallons would permit coverage of 90 acres per sortie.

The C-47 with insecticide spray system that was employed near the Bien Hoa airstrip and Chon Thanh could also be used for crop sprays and its suitability would be intermediate between that of the H-34 and the AD6. It has a capacity of approximately 675 gallons but spraying speed of only about 150 mph.

The 5 gallon garden sprayer would be useful for attacking small garden plots discovered by foot patrols. They could be used only in areas controlled by friendly forces. Here the 1 gallon of Purple herbicide could be used without added oil to reduce handling of inert carrier.

The feasibility of developing air droppable munitions capable of dispersing herbicides effectively in granular, liquid or vapor form should be explored. Such items should be aimable and could be dropped from altitudes above the range of ground fire.

V. Factors Influencing Time for Crop Attack

One of the most important factors affecting the time selected for crop attacks is the planting date. Since planting dates vary considerably from one part of Vietnam to another and from one crop to another careful planning must be carried out to achieve maximum effectiveness from the minimum quantity of agent and number of sorties.

Use should be made of the publication, "Agricultural Calendar of Vietnam - 1961", issued by Ministry of Agriculture - Vietnam in cooperation with Division of Agriculture USOM/Vietnam. In addition, a crop specialist (agronomist) from Ministry of Agriculture - Vietnam should be involved in target selection and timing of attacks.

Timing of attacks should also take into account the stage of crop development. Since young plants are more readily killed than older ones, the attack could be launched shortly after the crop emerges from the soil.

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While the V.C. might replant if the first crop were destroyed, the second crop could also be destroyed by spraying after it has emerged. Moreover, the second crop might not emerge if 1 gallon per acre of Purple had been used on the previous crop because of the residual toxic effect of Purple on germinating seeds. Cacodylic acid (Blue) has no or little residual toxic effect.

Sweet potatoes and manioc should be sprayed prior to root formation since killing the aerial portion of the plants will not immediately affect edibility of sweet potato or manioc roots if these are permitted to develop before spray applications.

VI. Hazards to Crops of Friendly Natives

The herbicides recommended for destroying Viet Cong crops are just as damaging to crops of friendly natives if applied or allowed to drift to the latter. Precautions should be taken to confine the spray deposit to the target areas. The following factors should be considered: 1) use large size drops (300 microns); 2) spray from low altitudes; 3) avoid spraying during high winds; 4) avoid spraying under neutral or lapse conditions.

In addition to the Viet Cong target crops these agents, particularly Purple, will also kill or render unproductive every other crop plant cultivated or non-cultivated with which they come in contact. Damage will be proportional to the dosage.

VII. Toxicity of Herbicides to Men and Animals

The 2,4-D type herbicides have been widely used in the United States for more than 15 years in food crops and on range land and are considered non-toxic to man and animals. The acute oral LD₅₀ for this type of compound ranges from 375 to 1200 mg/kg.

Cacodylic acid has an acute oral LD₅₀ for albino rats of 1350 mg/kg.

Both materials should be handled with care, should not be ingested and, if spilled on the skin, should be removed with soap and water at the earliest opportunity.

VIII. Soil Sterilization

In the event that chemical soil sterilization is desired to deny the Viet Cong the use of garden plots for crop production for several months, granular monuron could be applied at the rate of 40 lbs. per acre. A recommended device for applying granular material is the Swathmaster Spreader manufactured by Transland Company, Torrance, California. This

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could be installed in L-19 or L-20 aircraft with some aircraft modification. Other hoppers or granule dispersing devices could be custom built to fit any aircraft selected for the mission.

IX. Rapidity of Action

Rapidity of action of herbicidal chemicals on edible crops varies with the crop, its stage of development at time of spray application, the herbicide employed and the dose. Sweet potato and manioc plants about one month old can be killed in a week by the active ingredient in 0.1 gallon per acre of Purple. Plants two months old would die more slowly and, in the case of sweet potatoes, some small roots would be present and edible at time of death of the plant. If not harvested at this time, the roots would decay in the ground.

If the attack on sweet potatoes and manioc should be delayed until just prior to harvest, extremely heavy doses would be required to affect the edible roots. However, if the roots are harvested immediately after being sprayed, they will be completely edible and the spray application would have been without significant effect on quantity and quality of edible roots.

The response of rice and corn plants to spray applications of 1 gallon of Purple in 2 gallons of oil made one month after planting would be less spectacular but would result in either death or unfruitfulness of the plants.

Applications of cacodylic acid (Blue) to rice at any stage of development at a rate of 7 lbs. per acre in 3 gallons of solution would cause a yellow-brown desiccated appearance in less than a week. The plants would be killed or, if they survived, would not produce grain. Application of Purple to rice and corn when these crops are approaching maturity will, of necessity, be very high to produce significant results. If sprays are delayed too long (2 weeks before normal harvest), they can be ineffective.

X. Importance of Crop Attacks

Destruction of Viet Cong food crops in the field could be one of the most effective means of defeating the enemy. The Viet Congs currently are living on food crops grown in the areas that they control. If these crops are destroyed, the Viet Congs would be required to obtain food from other sources or starve. The additional burden of importing food would decrease their effectiveness in prosecuting the war.

The threat of starvation resulting from herbicidal sprays on mangrove areas at Hai Yen in An Xuyen province was one reason given by 112 Viet Cong who surrendered recently, even though no food crops were intentionally sprayed in that area.

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A message issued by the Viet Cong Provincial Commissar of Bien Hoa on 17 November 1961 to all district commissars discusses the Viet Cong plan of action if anti-crop attacks should be carried out by South Vietnam. It is obvious that they are very much concerned about anticrop attacks not only from the viewpoint of loss of food but also from the psychological effects. They state, "Be careful to prevent our members, cadres and the people from panic or fear". Their countermeasures to prevent food losses are to "harvest sooner, take off and hide crops carefully, cultivate scatteringly, etc."

XI. Recommendations for Killing Viet Cong Crops

In order to prevent confusion and to minimize errors in estimating plant age, the dose recommended for crop sprays is that required to kill the plant during its most resistant stage. The table below indicates the herbicides and equipment for use on specific crops. All crops should be sprayed between the time they emerge from the soil or are transplanted to about four weeks prior to their normal harvest date.

<u>Crop</u>	<u>Herbicide</u>	<u>Rate per Acre</u> ^{1/}	<u>Spray Volume</u> <u>Gals. per Acre</u>	<u>Equipment</u>
Rice	Blue	7 lbs.	3	H-34
Rice	Purple	1 gal.	3	H-34, AD6, C-47, C-123 ^{2/}
Corn	Purple	1 gal.	3	H-34, AD6, C-47
Manioc	Purple	1 gal.	3	H-34, AD6, C-47
Sweet Potato	Purple	1 gal.	3	H-34, AD6, C-47
Manioc	Pink&Green	1 gal.	3	H-34, AD6, C-47
Sweet Potato	Pink&Green	1 gal.	3	H-34, AD6, C-47

^{1/} This volume of Purple or Pink and Green should be dissolved in two gallons of fuel oil. Blue should be dissolved in sufficient water to yield 3 gallons of solution containing 7 pounds of the herbicide.

^{2/} C-123 is recommended for use only on large targets.

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Appendix D: Data Form for Herbicide Spray Missions

To Report

REVIEW AND EVALUATION of ARPA/OND "DEFOLIATION" PROGRAM
in SOUTH VIETNAM

Research Phase: 15 July 1961 -- 12 January 1962

Operational Phase: 13 January 1962 -- March 1962

APPENDIX E

DATA FORM FOR HERBICIDE SPRAY MISSIONS

Herbicide Spray Mission Data Sheet

Mission No.: _____

Date: _____ Time: _____

Target: Location _____ Size: _____

Type of Vegetation: Evergreen Forest _____ Mangrove _____ Scrub _____

Condition of Vegetation: Dormant _____ Growing _____

Spray Equipment: Nozzle size: _____ Number of Nozzles _____

Flow Rate: Gallons per minute _____

Pump Pressure: Pounds per square inch _____

Flight Altitude above Vegetation: _____ feet.

Aircraft Speed: _____ miles per hour

Estimated Wind Speed: _____ miles per hour. Direction _____

Aircraft Direction during Spray _____

Weather: Temperature _____ °F.

Overcast _____ Sunny _____

Rain occurred _____ hours after treatment.

Rain did not occur for twenty-four hours _____

Herbicide: _____

Gallons of Herbicide applied per acre: _____

AIRCRAFT TYPE: _____

IDENTIFICATION NUMBER: _____

PILOT AND CREW: _____

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Appendix E: Aircraft Dispersal Equipment for
Application of Herbicide Spray

To Report

REVIEW AND EVALUATION OF ARPA/OSD "DEFOLIATION" PROGRAM
in SOUTH VIETNAM

Research Phase: 15 July 1961 -- 12 January 1962

Operational Phase: 13 January 1962 -- March 1962

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APPENDIX E
AIRCRAFT DISPERSAL EQUIPMENT
FOR APPLICATION OF HERBICIDE SPRAY

In developing high volume dispersal equipment for installation in aircraft, first consideration must be given to the total gallons per minute and viscosity of the liquid the equipment will be required to handle.

A high volume herbicide spray dispersal unit for use in an aircraft similar to the Fairchild C-123, Douglas C-47, or Curtis C-46 must be able to deliver 450 gallons per minute at approximately 40 psi at the pump outlet to apply 3 gallons per acre. The pump, therefore, should be capable of delivering at least 600 gallons per minute free flow.

The required flow of 450 gpm is based on a flying speed of 150 mph and a possible effective swath of 500 feet. This results in a coverage rate of 150 acres per minute. This will require 150 gallons per minute flow to apply 1 gallon per acre and 450 gpm for 3 gallons per acre.

The tank and pumping unit comprising the MC-1, "Hour Glass" unit presently used in the C-123 would require major modification to deliver this volume of liquid, as would all pipe lines and booms.

In equipping a spray plane to apply these high application rates, every effort should be made to provide tank capacity for the maximum disposable load the aircraft is capable of carrying. If an aircraft can be assigned for spray missions only, its disposable load and productive capacity can be increased appreciably by removing certain military equipment which would serve no purpose in a spray plane.

The following basic items would be required in developing dispersal equipment capable of spraying at a flow rate of 450 gallons per minute.

Aluminum tank(s) with a capacity of 1000 gallons or more, equipped with a dump valve of not less than 7 inches inside diameter and free vent opening of not less than 3 inches inside diameter; also a suitable tank quantity gauge.

One gasoline engine powered centrifugal pump with not less than a 4 inch diameter inlet and 3 inch outlet capable of a free delivery of not less than 600 gallons per minute, or two gasoline engine driven centrifugal pumps, with not less than a 3 inch diameter inlet and 2.5 inch outlet. Each pump should be capable of a free delivery of not less than 300 gallons per minute.

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Three boom sections should be installed on the aircraft, one under each wing outboard of the engine nacelle and the third under the wing and fuselage between the engine nacelles, if possible, or back toward the tail under the fuselage.

The type and size of the nozzles selected should be capable of producing a spray with droplet size of approximately 300 microns diameter. This may be modified as R and D work dictates.

The number of nozzles operated at one time will depend on the application rate required to produce a specified volume per acre.

All pipe lines, hoses and control valves must be of sufficient inside diameter to carry the maximum flow anticipated through them without causing serious back pressure. All bends in the pipelines should be smooth and of as great a radius as possible. The use of 90° elbows should be held to an absolute minimum.

If two pumps are used, a one inch diameter pipe should be connected between the output manifolds of each pump to equalize the pressure in the system.

It is not the intent of the information contained in Appendix E to furnish adequate instructions for the fabrication of a high volume dispersal unit for a specific aircraft. It is intended to point out the basic parts required and to emphasize that a volume of 450 gallons per minute must be the equipment capability to apply 3 gallons per acre at 150 mph over a 500 foot swath.

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