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HERBICIDES USED IN SOUTHEAST ASIA

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TECHNICAL REPORT SAOQ-TR-69-11078

August 1969

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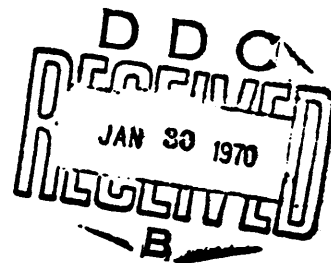
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Kelly Air Force Base, Texas 78241

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FOREWORD

This report was prepared by the Plant Sciences Laboratories, Department of the Army, Fort Detrick, Maryland under MIPR FD-2050-9-11078. The work was sponsored by the San Antonio Air Materiel Area (SAOQT), Kelly Air Force Base, Texas. Mr. Wayne E. Vandeventer was the Air Force representative on the contract.

Purpose of the study was to compile a technical report on herbicides used in Southeast Asia including historical background, test data, chemical and physical data and other pertinent information. The project was initiated on 29 November 1968 and completed in June 1969.

The report is intended as a manual of technical information and data on herbicides and their use in tactical military operations. The manual is designed for use by engineers, chemists, technical, supply, transportation and other personnel and agencies supporting the defoliant and anticrop operations.

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ABSTRACT

This report summarizes technical data and information on the herbicides ORANGE, ORANGE II, BLUE, and WHITE, currently used in Vietnam in defoliation, crop destruction and vegetation control programs; this manual is designed for personnel involved in support of these programs. A brief history of these programs is outlined for the period 1962 to 1969.

Physical, chemical and biological properties are tabulated for each agent with test data and information on their effectiveness in defoliation of tropical vegetation and in crop control.

Toxicological data summarized for the three agents indicate their low toxicity and lack of hazard to man and wildlife during or subsequent to spray application. Storage and handling precautions are given together with methods for disposal of spillage in loading and storage areas.

Characteristics of the equipment used in aerial and ground dissemination systems are described. Guidance is given for obtaining maximum efficiency in spray applications and on the relative hazards of spray drift and volatility of herbicides to nearby crops during defoliation spray missions.

Conditions influencing the effective use of chemicals in defoliation, crop control, and grass and total vegetation control include type of vegetation or crop, selection of agent, and rate and season of application.

A glossary of terms and characteristics of new candidate agents are included in appendixes.

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TABLE OF CONTENTS

Section	Page
I. INTRODUCTION	1
A. Purpose	1
B. Background	1
II. VEGETATION CONTROL CONCEPTS	3
A. Types of Chemicals Used in Vegetation Control	3
1. Contact Herbicides or Desiccants	3
2. Systemic or Translocated Herbicides	4
3. Defoliating Agents or Defoliants	4
4. Residual or Soil-Applied Herbicides	4
5. Growth Suppressants or Inhibitors	4
B. Military Uses of Vegetation Control Chemicals	5
1. Defoliant Operations	5
2. Anticrop Operations	5
3. Grass and Total Vegetation Control	5
4. Plant Growth Suppression	6
III. SELECTION AND EVALUATION OF AGENTS	7
A. Screening and Field Test Evaluation	7
B. Criteria for Selection and Development of Improved Agents	7
IV. HERBICIDES USED IN SOUTHEAST ASIA: PROPERTIES AND EFFECTIVENESS	9
A. ORANGE and ORANGE II	9
1. Physical and Chemical Properties	9
2. Biological Properties	10
3. Effectiveness As Defoliant	10
4. Effectiveness As Anticrop Agent	11
B. BLUE	13
1. General Description and Availability	13
2. Physical and Chemical Properties	14
3. Biological Properties	14
4. Effectiveness As Defoliant	15
5. Effectiveness As Anticrop Agent	16
C. WHITE	17
1. General Description and Availability	17
2. Physical and Chemical Properties	17
3. Biological Properties	18
4. Effectiveness As Defoliant	18
5. Effectiveness As Anticrop Agent	18

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Section	Page
V. TOXICOLOGICAL INFORMATION	19
A. Acute Oral Toxicity	19
B. Chronic Toxicity	20
C. Eye Contact	20
D. Skin Contact and Irritation	20
E. Toxicity to Fish and Aquatic Life	21
F. General Statement on Toxicity	21
VI. STORAGE AND HANDLING	23
A. Safety Precautions	24
B. Disposal of Spillage at Loading and Storage Areas	24
VII. AERIAL SPRAY SYSTEMS AND APPLICATION	26
A. Aerial Dissemination Systems	26
1. A/A45Y-1 Internal Defoliant Dispenser	26
2. UH-1B/D Helicopter Spray System (AGRINAUTICS)	27
3. Field Expedients	27
B. Optimal Conditions for Aerial Application	28
C. Spray Drift on Defoliation Missions and Proximity to Crops	29
D. Volatility and Crop Damage	30
E. Calibration Procedures for Aerial Spray Systems	32
1. Sampling Grid	32
2. Mass Deposition and Droplet Spectrum	32
3. Mass Median Diameter (MMD)	33
4. Swath Width	33
5. Percentage Recovery	34
VIII. GROUND DISSEMINATION SYSTEMS AND APPLICATION	35
A. Buffalo Turbine	35
B. Power-Driven Decontamination Apparatus (PDAA)	35
IX. CONDITIONS INFLUENCING EFFECTIVE USE OF HERBICIDES	36
A. Defoliant Operations	36
1. Target Vegetation	36
2. Selection of Agent	37
3. Rate of Application	37
4. Season of Application	37
B. Anticrop Operations	38
1. Target Crops	38
2. Selection of Agent	38
3. Rate of Application	38
4. Season of Application	39
C. Grass and Total Vegetation Control	39
1. Target Vegetation	39
2. Rate of Application	39
3. Season of Application	39
D. General Recommendations	39

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Section	Page
X. SUMMARY OF PROGRAM OBJECTIVES AND RESULTS	41
A. Tactical Aspects of the Defoliation Program	41
1. General Uses	41
2. Uses on Specific or Local Targets	41
3. Results	41
B. Tactical Aspects of the Crop Destruction Program	42
C. Scope of Defoliant and Anticrop Operations in RVN	43
D. Policy and Procedures in Operational Employment of Herbicides in RVN	43
REFERENCES	47

Appendixes	Page
A. Glossary of Terms	49
B. Candidate Agents for Vegetation Control	53

Figure	Title	Page
1.	Schedule for Defoliation and Crop Destruction Requests in RVN .	45

LIST OF TABLES

Table	Title	Page
I.	Effects of Application Rate, Season of Application, and Density of Forest Canopy on Defoliation by ORANGE	11
II.	Defoliation of Tropical Forests by ORANGE	12
III.	Corrosion Test of BLUE on Metals	13
IV.	Defoliation of Tropical Forests by BLUE	16
V.	Acute Oral Toxicity of ORANGE, BLUE, and Some of Their Components	20
VI.	Recommended Procedures for Filling Aircraft Defoliant Tanks Containing Residue of a Different Defoliant	24
VII.	Effect of Spray Droplet Size on Spray Drift	29
VIII.	Rate of Fall and Downwind Drift of ORANGE from 150-Foot Altitude in 3-, 6-, and 9-mph Winds	29
IX.	Relative Volatility of Common Chemicals	31
X.	Synopsis of Use Recommendations for Herbicides in Southeast Asia	40

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SECTION I

INTRODUCTION

A. PURPOSE

The purpose of this report is to provide information on the herbicides used for defoliation, crop control, and other types of vegetation control in military operations in Southeast Asia. Emphasis is given to the aerial application of these agents and the conditions influencing their effective use. Research data from field tests in tropical areas other than the Republic of Vietnam (RVN) are presented for the basic agents in operational use. Lists of terms and of additional candidate agents are presented in appendixes. The report is designed to assist military personnel involved in the field use of defoliants and herbicides.

B. BACKGROUND

The defoliation and anticrop programs, as counterinsurgency measures in RVN, were introduced and developed by the Advanced Research Projects Agency, Office of the Director of Defense Research and Engineering, Department of Defense, as a part of PROJECT AGILE. In 1961, the joint US/RVN development program established a series of tasks that included Task 2 for crop destruction and Task 20 for defoliation. In response to the objectives of the two tasks, chemical spray tests were accomplished in Vietnam by the RVN Air Force with experimental dissemination systems and off-the-shelf commercial herbicide preparations. Despite the serious limitations of the components, the results of the tests demonstrated clearly that available growth-regulator and desiccant chemicals were capable of causing defoliation of the tropical forests and destroying food crops. The first USAF C-123/MC-1 (Hourglass) spray systems and the agents of choice, PURPLE and BLUE,* reached Vietnam in January 1962, and Operation RANCH HAND was initiated with the mission to accomplish defoliation and anticrop operations.

The C-123/MC-1 system was designed to deliver its 1,000-gallon payload at a rate adequate to obtain 1 gallon/acre deposits on target. Evaluation of results from the earliest spray missions showed that greater deposits were required, and the system was modified to provide for ground deposits of 3 gallons/acre.¹

* Agent PURPLE consisted of a mixture of n-butyl 2,4-dichlorophenoxyacetate (2,4-D), n-butyl 2,4,5-trichlorophenoxyacetate (2,4,5-T) and iso-butyl 2,4,5-trichlorophenoxyacetate. Eventually, PURPLE was replaced by ORANGE. The original agent BLUE consisted of a water-soluble powder that contained 65% cacodylic acid (dimethylarsinic acid) as its active ingredient. A neutralized, liquid formulation of cacodylic acid, its sodium salt, and a surfactant later supplanted the first BLUE.

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The history and development of the RANCH HAND program and the accompanying research and development of herbicides and defoliants are outlined in detail in a review by W.F. Warren.²

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SECTION II

VEGETATION CONTROL CONCEPTS

A. TYPES OF CHEMICALS USED IN VEGETATION CONTROL

Chemicals may be used for various purposes in the control or modification of plant growth, such as killing, defoliating, desiccating and inhibiting or suppressing growth.

Chemicals that kill or damage plants are called herbicides, as defined by Department of Army and Joint Services in AR 320-5.³ Some organic chemicals are considered growth regulators and are effective in minute amounts for controlling or modifying plant processes by stimulating or inhibiting growth. The same growth-regulating chemical (for example 2,4-dichlorophenoxyacetic acid) may stimulate growth when applied to plants at extremely low dosages, but may be inhibitory or lethal at higher concentrations. In a broad sense, the term herbicide has been used for any chemical used in killing plants or interrupting their normal growth. Used in this sense, the term herbicide would include growth-suppressant or inhibiting chemicals (such as maleic hydrazide, cycocel, etc.) that stop or inhibit normal growth.

Herbicides may be classified on the basis of their effects upon plants and the site of application (foliage or soil). Foliage-applied herbicides include: (i) contact herbicides or desiccants that kill primarily by contact with plant tissue rather than as a result of translocation and movement within the plant, and (ii) systemic or translocated herbicides that are absorbed by the plant and are moved (translocated) within the plant from the point of entry. Soil-applied or residual herbicides kill germinating seeds and established plants by uptake of the chemical from the soil.

Herbicides may be further characterized as selective and nonselective. A selective herbicide may kill some plants but cause little or no effect on others. By contrast, a nonselective herbicide exhibits a broad spectrum of herbicidal effect on most plant species.

1. Contact Herbicides or Desiccants

Contact herbicides or desiccants cause rapid desiccation or dehydration of the foliage or plant part covered by the chemical. The chemical shows little or no movement in the plant from the point of application. Thorough spray coverage is thus essential to secure maximum desiccation. Desiccants may cause leaf fall or defoliation on some plants; in other species, the leaves may dry and shrivel up but remain attached to the plant. Desiccants normally do not kill perennial woody and herbaceous plants, and in the tropics new foliage may develop in 30 to 90 days after application. Agent BLUE is an example of a desiccant.

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2. Systemic or Translocated Herbicides

Systemic or translocated herbicides are growth-regulating or hormone-type chemicals that are absorbed and moved throughout the plant when applied to the foliage. Systemic herbicides interfere with the photosynthetic, respiratory, and other processes in plants, leading to leaf fall and ultimate death of the plant. Some plant species are highly resistant to this class of chemicals and outwardly may appear unaffected. In general systemic herbicides are most effective on broadleaf plants in an active state of growth. Agents ORANGE, WHITE, and their active components are examples of systemic herbicides that are used as defoliating agents on woody plants and broadleaf vegetation. Dalapon or Kenapon (see Appendix B) is a systemic herbicide specific for the control of grasses.

3. Defoliating Agents or Defoliants

Defoliating agents or defoliant are chemicals that cause trees, shrubs and other plants to shed their leaves prematurely.³ Both contact and systemic herbicides may cause defoliation. However, a nonherbicidal or true defoliant is a growth-regulating chemical that causes defoliation or leaf fall without killing or seriously affecting the plant. Several chemicals are effective as defoliant of cotton and other agricultural crop plants, but no satisfactory nonherbicidal defoliant has been developed for woody vegetation. Research is continuing in an effort to develop a militarily useful true defoliating agent.

4. Residual or Soil-Applied Herbicides

Residual or soil-applied herbicides are essentially chemicals with a low solubility in water that prevent plant growth when present in the soil. The chemicals are absorbed through the root system and are dependent upon effective rainfall and available soil moisture for uptake. The duration of effect is governed by the rate of application and the rate of depletion caused by leaching, chemical degradation, and microbial decomposition of the chemical in the soil. The chemicals may be applied either in liquid sprays or in granular or pelleted formulations. Wettable powders used in liquid sprays require relatively large volumes of water and agitation during application. Soil-applied or residual herbicides are useful in the control of perennial grasses that are not readily affected by systemic herbicides and desiccants. Bromacil, Tandex, and monuron (see Appendix B) are examples of residual herbicides capable of control of perennial grasses and other vegetation for periods of several months to a year or more.

5. Growth Suppressants or Inhibitors

Growth suppressants or inhibitors are growth-regulating chemicals that inhibit or retard growth and that may be used to maintain vegetation at a desired height or stage of growth. Maleic hydrazide and cycocel are examples of chemicals that have been used for retarding growth of grasses

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and other plants under temperate-zone conditions. When applied at rates higher than required for growth inhibition, these chemicals act as selective herbicides. Thus, the wide variability in species response and lack of uniformity in performance under field conditions have restricted the use of this type of chemical for vegetation control. Suitable rates and procedures have not been established for tropical regions.

B. MILITARY USES OF VEGETATION CONTROL CHEMICALS

1. Defoliant Operations

Defoliant operations involve the employment of defoliating agents in military operations on heavily vegetated areas so as to expose the terrain to better observation.³ The primary objective of defoliation is to reduce cover and concealment of enemy installations and enemy forces along lines of communication and thus restrict ambush possibilities. In addition, defoliation may be used in clearing forest or other vegetation from friendly fields of fire, minefields, base camp perimeters, and other critical military facilities.

Requirements for short-term defoliation (1 to 3 months) may be satisfied with a desiccant such as BLUE. Long-term defoliation (4 to 12 months or more) can be achieved with systemic herbicides such as ORANGE and WHITE.

2. Anticrop Operations

Anticrop operations involve the employment of anticrop agents in military operations to destroy the enemy's source of selected food or industrial crops.³ Both systemic herbicides and desiccants may be used for this purpose. Broad-leaved crops are generally susceptible to the 2,4-D and 2,4,5-T components of ORANGE. Grasses and cereal crops, such as rice, wheat, corn, sorghum, millet, etc., as well as a number of broad-leaved crops, respond readily to applications of the desiccant BLUE.⁴

Reductions in yields of rice may be accomplished by relatively low doses of BLUE (0.25 to 0.5 pound/acre) with little or no effect on the vegetative growth of the plant. Higher dosages will result in rapid browning and death of the plants at most growth stages.

3. Grass and Total Vegetation Control

The resistance of perennial grasses to most systemic herbicides leads to the need for specific methods for control of grasses and grass-shrub vegetation. In areas of dense, tall tropical grasses, effective control may require initial knockdown or removal by bulldozing or root-plowing (Roma-plowing) followed by the use of chemicals to prevent or minimize regrowth.

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BLUE is effective in the control of annual grasses and some perennial species. It acts as a desiccant at rates of 1 pound/acre or more, burning or browning back the current foliage growth. Resistant grasses, such as elephant grass, wild cane, giant seed, etc., may require repeated application of BLUE for control and maintenance.

Dalapon in the liquid ester form (Kenapon) has shown promise for control of tropical grasses as a systemic herbicide specific for grasses.

Diesel fuel has been utilized as a contact herbicide for control of grasses in perimeter areas where other chemicals would create a hazard to closely adjacent crops or other desirable vegetation.

For long-term vegetation control in base-camp perimeters, ammunition dumps, minefields, and other sites requiring control of grasses and scrub or regrowth woody vegetation, soil-applied herbicides such as bromacil, Tandex, or monuron are the preferred type of agent. These chemicals may be safely employed in situations where the residual chemical in the soil or minor lateral displacement of chemical on the soil surface due to runoff do not present hazards to adjacent crops or desirable vegetation. Currently, the use of soil-applied herbicides has not been approved in RVN.

4. Plant Growth Suppression

Military requirements have developed in some areas for the maintenance of grasses and other vegetation at a low stature by growth suppression or inhibition. Growth-regulating chemicals, such as maleic hydrazide, cycocel, etc., offer some promise for control, but suitable rates and procedures have not been established for tropical regions.

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SECTION III

SELECTION AND EVALUATION OF AGENTS

A. SCREENING AND FIELD TEST EVALUATION

The Department of the Army at Fort Detrick has mission responsibility for the selection and development of defoliants and herbicides for military purposes. A continuing review and evaluation is made of commercially available herbicides and growth-regulating chemicals, as well as newly synthesized compounds, in the search for improved agents.

Initial screening is conducted on 7-day-old plants of six species, with evaluations of responses following foliar spray applications at 0.1 and 1.0 pound/acre. Active chemicals are screened for defoliant activity on 14-day-old Black Valentine beans at the same rate of application. Selected chemicals are then tested for defoliation response in the greenhouse on 8 to 10 woody plants at rates of 1, 5 and 10 pounds/acre of active ingredient or acid equivalent. Comparable small-plot tests are conducted on crop species to determine herbicidal responses of candidate agents under field conditions.

Field tests of candidate defoliants are conducted at CONUS and OCONUS locations with both aerial and ground spray equipment. Recent aerial test programs have been conducted with the UH-1B/D helicopter sprayer in studies of variables, such as rates and volumes of application, season of application, and species response.

Evaluations include determinations of defoliation or canopy removal, desiccation or contact injury, and plant kill.

B. CRITERIA FOR SELECTION AND DEVELOPMENT OF IMPROVED AGENTS

1. Broad Spectrum of Activity

The agent should be active on many kinds of plants and vegetation. Nonselectivity is a goal.

2. Rapid in Action

Defoliation within 3 to 5 days after application is an accepted goal for improved defoliants.

3. Suitable for Application with Air or Ground Equipment

Liquid agents with high concentrations of active ingredients are preferred.

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4. Nontoxic to Man and Animals

Selected agents should be nontoxic to man, domestic animals, and all forms of fish and wildlife, both at the time of and subsequent to application.

5. Stable in Storage

Selected chemicals should remain stable under storage conditions ranging from freezing temperatures to tropical heat.

6. Effective in Low Dosage

The selected agent should be effective at low dosage rates consistent with the requirements for adequate coverage of the target vegetation.

7. Noncorrosive

Agents should be noncorrosive to storage containers, dissemination systems, and aircraft and support equipment.

8. Cost

Effectiveness and utility of the agent should be given first consideration; unit cost is not ignored, but it is of secondary importance.

9. Readily Available or Capable of Manufacture

Selected agents should be producible in large quantities at an acceptable cost.

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SECTION IV

HERBICIDES USED IN SOUTHEAST ASIA: PROPERTIES AND EFFECTIVENESS

A. ORANGE AND ORANGE II

ORANGE is the color designation for a 50:50 mixture (v/v) of n-butyl esters of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T).

ORANGE II is a mixture of equal parts (v/v) of n-butyl ester of 2,4-D and isooctyl ester of 2,4,5-T. The biological effectiveness of this mixture is the same as that of ORANGE. ORANGE II was recommended for use at a time when the field requirements for ORANGE exceeded availability and limited quantities of the isooctyl ester of 2,4,5-T could be obtained.

Approximate cost of ORANGE and ORANGE II is \$7.10 per gallon.

1. Physical and Chemical Properties

	<u>ORANGE</u>	<u>ORANGE II</u>
Physical State	Liquids at room temperature	
Color	Clear, reddish brown to straw-colored	
Solubility	Soluble in diesel fuel and organic solvents. Insoluble in water.	
Freezing Point, C	7 to 8	9
Flash Point	146 C (295 F)	Unknown
Specific Gravity at 25 C	1.275 to 1.295	1.220 to 1.242
Weight, lb/gal:		
Total ester	10.7	10.2
Acid equivalent	8.6	7.6
Viscosity, centipoises, at:		
0 F	5,000	Unknown
20 F	940	Unknown
32 F	390	Unknown
50 F	134	Unknown
75 F	43	67
100 F	24	27
Vapor Pressure	< 1 mm Hg at 35 C	

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Corrosiveness

Noncorrosive on most metals.
Deleterious to some paints,
natural rubber, and neoprene.
Teflon, viton, polyethylene and
butyl rubber are resistant.

2. Biological Properties

Both ORANGE and ORANGE II are effective defoliants and herbicides on a wide array of woody and broadleaf herbaceous species. Grasses, bamboos, and other monocotyledonous plants are less affected. Biological properties, toxicity, and other data cited for ORANGE are also applicable to ORANGE II.

Absorption following application of ORANGE or ORANGE II to the foliage occurs within a few hours, and the chemical is translocated to other parts of the plant in the sap stream. Herbicidal response is caused by disruption of the respiration, metabolic, and cell division processes in plants.

The 2,4-D and 2,4,5-T components of ORANGE are decomposed by soil microorganisms, and the chemical will generally disappear from soils within 1 to 3 months after application.

ORANGE and its component n-butyl esters of 2,4-D and 2,4,5-T are sometimes characterized as volatile herbicides because the vapors are relatively phytotoxic. However, the vapor pressure of ORANGE is less than 1 mm of mercury at 35 C, equivalent to that of No. 2 diesel fuel, indicating that volatility or vapor movement is relatively minor. The vapor pressure of the isooctyl ester of 2,4,5-T, which comprises 50% of ORANGE II, is slightly lower than that of ORANGE, indicating that volatility of ORANGE II is less than that of ORANGE.

Laboratory tests of the evaporation rate of ORANGE show that the concentrated esters in exposed droplets or films actually gain weight by absorption of moisture from the atmosphere. Lateral movement of ORANGE due to volatility alone is believed to be negligible.

3. Effectiveness As Defoliant

ORANGE and ORANGE II are effective defoliants of forest vegetation in temperate and tropical regions. Under tropical conditions, application rates of 3 gallons/acre are needed for defoliation, particularly in multiple canopy forest (Table I). Grasses and bamboos may exhibit browning of foliage and partial topkill but recover rapidly. Under temperate conditions, application rates of 1 to 1.5 gallons/acre appear to be adequate for effective defoliation.

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TABLE I. EFFECTS OF APPLICATION RATE, SEASON OF APPLICATION,
AND DENSITY OF FOREST CANOPY ON DEFOLIATION BY ORANGE*

Spray Deposit, gal/acre	% Maximum Defoliation			
	Rainy Season Application		Dry Season Application	
	Single Canopy	Multiple Canopy	Single Canopy	Multiple Canopy
3.0	88	75	82	67
2.5	79	66	71	61
2.0	76	59	64	54
1.5	76	52	58	48
1.0	76	49	52	42

* Tests included ORANGE and its predecessor PURPLE; bioeffects of the two compounds are identical. Data based on OCONUS defoliation test in Thailand.⁶

The typical response of mixed woody vegetation to an application of ORANGE shows first as a browning and discoloration of the foliage within a period of 1 or 2 weeks. Foliage of the more susceptible species may turn brown very rapidly, and subsequent leaf drop will occur over a period of 1 to 2 months. Under tropical conditions, maximum defoliation may occur at 2 to 3 months after spray application (Table II). As herbicidal response proceeds, the branches die back progressively from the tip, accompanied by defoliation. When only partial kill of the individual plant occurs, regrowth and new foliage will develop from the main stems and larger branches.

Under tropical forest conditions, satisfactory levels of defoliation may persist for 4 to 12 months or more, after which regrowth and replacement vegetation may require retreatment.

4. Effectiveness As Anticrop Agent

ORANGE and ORANGE II are effective in the control of most broad-leaf crops. Recommended rate of application of ORANGE and ORANGE II for broadleaf crop control is 1 gallon/acre. However, for convenience and simplification in programming defoliation and crop destruction targets in the RANCH HAND program, applications of ORANGE and ORANGE II for crop targets are made uniformly at 3 gallons of undiluted chemical per acre. In instances when the UH-1B/D helicopter spray system is used for specific crop targets, the recommended rate of 1 gallon per acre of ORANGE or ORANGE II may be used and diluted 1:2 with diesel fuel for a total application rate of 3 gallons of the agent:fuel mixture per acre.

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TABLE II. DEFOLIATION OF TROPICAL FORESTS BY ORANGE

Location* and Date	% Defoliation at				
	1 mo	3 mo	6 mo	9 mo	12 mo
Luquillo, Puerto Rico⁷					
Tropical Evergreen Forest					
April 1966	73	79	66	-	55
October 1966	46	62	75	-	-
Hilo, Hawaii⁸					
Ohia - Treefern Forest					
December 1966	45	60	62	58	55
Kauai, Hawaii⁸					
Tropical Shrub & Forest					
December 1967	71	84	80	-	-
Thailand⁸					
Tropical Dry Evergreen Forest					
May 1964	-	90	66	50	30
September 1964	40	57	60	45	32
December 1964	15	52	52	37	27

* Three gallons per acre applied at all locations.

Actually, the recommended rate of 1 gallon per acre has a substantial safety margin. Thus, ORANGE applied at the rate of 1 pound of acid equivalent or 1 pint per acre is sufficient to kill most broadleaf crops of tropical and temperate regions. Annual tropical crops killed by ORANGE at 1 gallon/acre applied at any growth stage include:

Beans	Melon	Sesame
Cabbage	Peanuts	Soybeans
Cotton	Pepper	Tobacco
Gourd	Ramie	Watermelon
Jute		

Root or tuber crops that show greatest reductions in yields from application of ORANGE during early growth stages include:

Manioc or cassava	Taro
Potatoes	Yams
Sweet potatoes	

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Perennial and woody tropical crop species vary widely in response to direct applications of ORANGE. Jackfruit, kapok, papaya and roseapple or cainito are highly susceptible to herbicide damage. Moderately susceptible crops include:

Banana	Mango	Pomelo
Castor bean	Mulberry	Roseapple
Guava	Pineapple	Tea

Citrus and rubber may be defoliated by high rates of ORANGE but will generally refoliate within several months. Coconut and betelnut palms are relatively resistant.

B. BLUE

1. General Description and Availability

BLUE is the code designation for a liquid formulation of sodium cacodylate, the sodium salt of cacodylic acid or dimethylarsinic acid. The neutralized formulation contains the sodium salt of cacodylic acid, cacodylic acid, a surfactant, and an antifoam agent. Cacodylic or dimethylarsinic acid is an organic arsenical. Unlike the inorganic arsenicals, such as sodium arsenite, which contain arsenic in the toxic trivalent form, cacodylic acid and its salt contain pentavalent arsenic, which is of extremely low toxicity to animal life.

a. Composition

Minimum content of 21% sodium cacodylate plus additional cacodylic acid to make a total dimethylarsinic acid equivalent of not less than 26% on a weight basis.

Surfactant: 3 to 5% by volume

Antifoam agent: 0.5% by volume

Weight of active ingredient: 3.0 pounds per gallon

Agent BLUE procured prior to July 1969 consisted of the Ansul Company formulation, Phytar 560G, which contained 3.1 pounds per gallon of cacodylic acid equivalent, 5% surfactant, and 0.5% antifoam agent.

b. Availability

Ansul Company has been the principal manufacturer of BLUE, supplying a formulation designated as Phytar 560G.

Formulations of sodium cacodylate meeting the specifications for BLUE are also available from Chapman Chemical Company, Diamond Shamrock Corporation, and Vineland Chemical Company.

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c. Approximate Cost

\$3.35 per gallon

2. Physical and Chemical Properties

	BLUE
Physical State	Free-flowing liquid
Color	Reddish or brownish
Solubility	Soluble in water and alcohol. Insoluble in oils.
Freezing Point, F	-22
Flammability	Nonflammable
pH	6.7 to 7.3
Specific Gravity at 25 C	1.31
Weight, lb/gal:	
Formulation	10.9 to 11.0
Cacodylic acid equivalent	3.0 to 3.1
Viscosity, centipoises, at:	
(Based on Phytar 560G containing 5% surfactant and 0.5% antifoam)	
50 F	27
75 F	14
95 F	10
Corrosiveness (see Table III)	Corrosive to zinc and mild steel. Noncorrosive to brass, copper, aluminum and tin.

3. Biological Properties

BLUE is a rapid-acting desiccant or contact herbicide that causes browning and dehydration of treated portions of plants. At the rates of application used for defoliation, the chemical exhibits little or no systemic action or translocation within the plant.

In contact with the soil, BLUE is quickly inactivated by surface adsorption and ion exchange. It is nonvolatile and undergoes no loss by photodecomposition.

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TABLE III. CORROSION TEST OF BLUE ON METALS*

Metal	% Wt. Loss at 1 Month	pH		Remarks
		Initial	Final	
Aluminum	0.55	7.55	7.60	Slight initial reaction; white flocculent precipitate formed.
Brass	0.14	7.55	7.64	No initial reaction; white flocculent precipitate formed.
Copper	0.33	7.55	7.59	No initial reaction; no solid precipitate formed; solution changed to green and amber color.
Mild steel	3.62	7.55	7.71	Rapid initial reaction; much gray flocculent precipitate formed.
Tin	0.45	7.55	7.59	No initial reaction; light gray suspended flocculent formed.
Zinc	20.21	7.55	9.25	Rapid chemical reaction and color change; heavy granular precipitate formed.

* Data from Plant Sciences Laboratories, Fort Detrick, based on submersion of metal strips in Phytar 560G for 30 days at room temperature, September 1967.

4. Effectiveness As Defoliant

When applied at a rate of 3 gallons/acre to broad-leaved herbaceous, woody or grass vegetation, BLUE causes a rapid browning or desiccation with accompanying shriveling and leaf fall of some woody species. Noticeable browning or discoloration is evident in one day, and maximum defoliation may occur in 2 to 4 weeks (Table IV). The recommended application rate of 3 gallons/acre is equivalent to 9.3 pounds per acre of BLUE.

BLUE may be used for short-term defoliation of woody vegetation. It is highly effective in topkill of perennial grasses. Regrowth of some species, such as elephant grass, wild cane, cogongrass, etc., is likely to occur in 1 to 2 months after treatment, thus requiring repeated spray applications.

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TABLE IV. DEFOLIATION OF TROPICAL FORESTS BY BLUE

Location and Rate	% Defoliation				
	Days after Treatment				
	7	14	30	60	120
Las Marias, Puerto Rico, 1967 ^a					
Lower Cordillera Forest					
12 lb/acre	51	60	70	57	43
Kauai, Hawaii, 1967 ^a					
Tropical Shrub & Forest					
9 lb/acre	37	45	54	51	25
12 lb/acre	40	56	62	54	26
15 lb/acre	40	56	59	57	26
Thailand, 1964-1965 ^b					
Tropical Dry Evergreen Forest					
3.4 lb/acre	15	42	52	37	15
6.0 lb/acre	30	55	65	43	25

5. Effectiveness As Anticrop Agent

BLUE is the agent of choice for destruction of cereal or grain crops. For crop destruction missions on rice and other grass crops with C-123 aircraft, a basic rate of application of 3 gallons/acre of BLUE is used. For specific crop targets, the recommended rate for the UH-1B/D or field expedient systems for helicopters is 1 gallon/acre diluted with 2 gallons of water for a total spray deposit volume of 3 gallons/acre.

Tests of BLUE have given 100% yield reduction of rice with applications of 1 pound/acre in the vegetative and early flowering stages of growth. Corn, sorghum, wheat and oats have shown similar responses. The recommended rate of 1 gallon/acre thus has an ample safety factor for rice.

Aerial application at the usual delivery volume of 3 gallons of undiluted BLUE will result in slightly more rapid desiccation and crop destruction than at 1 gallon/acre. Effects of the chemical are evident within 12 to 24 hours; death of plants occurs within a few days.

BLUE is water-soluble, and application should not be made during or just prior to heavy precipitation.

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C. WHITE

1. General Description and Availability

WHITE is the code designation for Tordon 101, a liquid formulation containing picloram (4-amino-3,5,6-trichloropicolinic acid) and 2,4-D in the form of tri-isopropanolamine salts.

a. Composition

Based on weight of salt: picloram, 10.2%; 2,4-D, 39.6%; and inerts, 50.2%.

Based on weight of active ingredient or acid: picloram, 5.7% or 0.54 pound/gallon; 2,4-D, 21.2% or 2.0 pounds/gallon, remainder consisting of water, wetting agent, and other inert ingredients.

b. Availability

WHITE or Tordon 101 is a proprietary formulation produced by Dow Chemical Company.

c. Approximate Cost

\$6.40 per gallon

2. Physical and Chemical Properties

	WHITE
Physical State	Viscous liquid
Color	Dark brown
Solubility	Miscible with water. Insoluble in oils. Active components are soluble in water.
Flash Point, F	95
Specific Gravity at 25 C	1.15
Viscosity, centipoises, at:	
50 F	343
75 F	125
100 F	95
Corrosiveness	Noncorrosive to metals and materials used in spray equipment.

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The picloram component is a white powder, soluble in water (430 ppm) and highly soluble in alcohol and acetone. Picloram is non-volatile with a vapor pressure of 6.16×10^{-7} mm Hg at 35 C.⁹ The vapor pressure of the tri-isopropanolamine salt is unknown.

3. Biological Properties

WHITE is a mixture of two systemic herbicides, picloram and 2,4-D. The active ingredients are readily absorbed by foliage. Additionally, picloram is readily absorbed by the root system and translocated rapidly within the plant.

The picloram component of WHITE is more persistent in soils than ORANGE or BLUE. Microbial decomposition is limited, and the principal removal or loss of picloram from soils occurs by leaching. In sparse vegetation areas at rates of 3 gallons/acre the picloram in WHITE may persist in some soils for as long as 1 year or more.

Both the picloram and 2,4-D components are stable, but picloram is subject to limited decomposition by sunlight and ultraviolet radiation.

4. Effectiveness As Defoliant

WHITE and its active components are selective systemic herbicides effective principally on broadleaf herbaceous and woody plants at relatively low rates of application. Most grasses and monocotyledonous plants, including Nipa palm, are resistant to picloram. Temperate zone conifers are susceptible to picloram. Herbicidal action on woody plants is slow, and full defoliation may not occur for several months after spray applications.

Neither WHITE nor ORANGE is recommended to defoliate areas very close to crops or rubber plantations.

5. Effectiveness As Anticrop Agent

WHITE has not been recommended for use on crops because of its persistence in soils. Both picloram and 2,4-D, the active components of WHITE, are extremely effective herbicides on broadleaf crop species. Applications of as little as 0.05 to 0.10 pound/acre of picloram have caused substantial yield reductions of garden beans, soybeans, Irish potatoes, peanuts, sweet potatoes, and other crops.¹⁰ Soybeans, cotton, and tomatoes are very sensitive to picloram. Seedlings of these crops show visible symptoms of herbicide effect with residual amounts of picloram in the soil of less than six parts per billion. Tomatoes may be killed by sprays containing 1.0 ppm of picloram.

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SECTION V

TOXICOLOGICAL INFORMATION

One of the essential prerequisites in the selection of herbicides for defoliation and anticrop programs is a low mammalian toxicity. ORANGE, BLUE, and WHITE are all characterized by low toxicity to man, fish, and wildlife, and these chemicals present no hazard to animal life on target areas during or after spray applications. It is emphasized that BLUE or cacodylic acid (dimethylarsinic acid) is an organic compound containing arsenic in the innocuous pentavalent form rather than the toxic trivalent form, as in sodium arsenite.

Chemicals may be rated in toxicity according to the following classification, based on the probable lethal human dose for a single ingestion or acute oral toxicity:¹¹

<u>Class</u>	<u>Acute Oral Toxicity, LD₅₀, mg/kg of body weight</u>	<u>Lethal Dosage for 150-lb Man</u>
Highly toxic	50 and below	Few drops to 1 teaspoon
Moderately toxic	50 to 500	1 teaspoon to 1 ounce
Mildly toxic	500 to 5,000	1 ounce to 1 pint or pound
Nontoxic	Above 5,000	1 pint to over 1 quart

The general concept of toxicity of chemicals to man and wildlife includes the effects of a single ingestion or acute oral toxicity and long-term or chronic effects of the chemical on the skin, eyes, inhalation and other types of physical contact. Most of the ordinary chemicals with which we come in contact, such as table salt, aspirin, etc., have a degree of toxicity when ingested. When all aspects of toxicity are considered, agents ORANGE, BLUE, and WHITE have no serious limitations in their use.

A. ACUTE ORAL TOXICITY

Acute oral toxicity data for the three primary agents and their components are presented in Table V. Data are expressed as LD₅₀ in milligrams per kilogram (mg/kg) of body weight or the dosage lethal to 50% of the test animals. The white rat is the standard test animal used.

The LD₅₀ values for the three agents, ORANGE, BLUE and WHITE, show low acute oral toxicity. Both BLUE and WHITE are safer than aspirin when ingested in a single dose.

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TABLE V. ACUTE ORAL TOXICITY OF ORANGE, BLUE, AND SOME OF THEIR COMPONENTS*

	LD ₅₀ , mg/kg of Body Weight			
	Rat	Rabbit	Sheep	Cattle
ORANGE	566			
BLUE	2,600			
WHITE	3,080		2,000	3,163
2,4-D	620	424		
2,4,5-T	481	712		
Picloram	8,200	2,000	1,000	750
Aspirin	1,750			

* Data compiled from Weed Society of America,⁹ House, et al.,¹¹ McNamara,¹² Ansul Company,¹³ and Weimer, et al.¹⁴

B. CHRONIC TOXICITY

Feeding tests carried out for 60 to 90 days or more on livestock and large animals have shown no significant hazards from the chemicals. Cattle fed the 2,4,5-T component of ORANGE at rates up to 161 mg/kg daily for 78 days showed no adverse effects.¹² Dairy cattle fed BLUE for 60 days at the rate of 24.5 mg/kg gave no residue of arsenic in the milk and no storage of arsenic on a cumulative basis.¹³ Similarly, cattle fed the picloram component of WHITE showed no evidence of the chemical in milk, and 98% of the administered chemical was recovered in the urine.¹⁴

C. EYE CONTACT

WHITE applied directly to the eyes of rabbits caused moderate transient eye irritation but no significant corneal injury. In general, ORANGE, BLUE and WHITE present only a minor hazard from direct eye contact.

D. SKIN CONTACT AND IRRITATION

Slight irritation may be caused by prolonged contact of the agents on the skin. ORANGE and WHITE exhibit little or no skin absorption. Prolonged contact with BLUE should be avoided to minimize absorption of cacodylic acid; excessive exposure is evidenced by a pronounced garlic odor in the breath. As stated earlier, skin contact with any of the chemicals should be avoided, and spillage should be removed by flushing liberally with water.

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Inhalation of any of the three agents appears to have little or no effect on humans.

E. TOXICITY TO FISH AND AQUATIC LIFE

In general, the three agents ORANGE, BLUE and WHITE are low in toxicity to fish and aquatic life. Concentrations of herbicide in water are generally expressed in parts per million (ppm). One ppm is equivalent to 2.72 pounds of herbicide per acre-foot* of water. Thus, if 3 gallons of ORANGE were sprayed on an acre of water one foot deep, the concentration would be approximately 11 ppm.

Extensive tests of the widely used 2,4-D and 2,4,5-T components of ORANGE show that toxicity to fish varies considerably with the type of fish, the duration of exposure to chemical, and the salt or ester formulation employed.¹⁸ For example, the LD₅₀ in 48 hours for the dimethylamine salt of 2,4-D for bluegill sunfish is 166 to 458 ppm, while in 96 hours for fathead minnows it is 10 ppm. Fingerling bluegills showed mortality of 40 to 100% from the butyl ester of 2,4-D at concentrations of 1 to 5 ppm. Ester forms of 2,4-D and 2,4,5-T are somewhat more toxic than pure acid or salts; the latter are normally used for control of aquatic vegetation without injury to fish.

The cacodylic acid component of BLUE had no lethal effect on three kinds of fish subjected to concentrations of 100 ppm for 72 hours. Median tolerance limits of fish to WHITE ranged from 64 to 240 ppm.

F. GENERAL STATEMENT ON TOXICITY

On the basis of a review of the toxicity data for ORANGE, BLUE and WHITE by the Midwest Research Institute,¹¹ the following conclusions were drawn:

"(1) The direct toxicity hazard to people and animals on the ground is nearly nonexistent.

"(2) Destruction of wildlife food and wildlife habitat will probably affect wildlife survival more than any direct toxic effects of the herbicides.

"(3) The application of ORANGE or WHITE alongside of rivers and canals or even the spraying of the water area itself at the levels used for defoliation is not likely to kill the fish in the water.

* A 1-acre area covered to a depth of 1 foot.

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"(4) Food produced from land treated with herbicides will not be poisonous or significantly altered in nutritional quality; if residues of a more persistent herbicide, such as picloram, should carry over to the next growing season, it would retard plant growth rather than concentrate some toxic residue in the crop.

"(5) Toxic residues of these herbicides (ORANGE, WHITE, and BLUE) will not accumulate in the fish and meat animals to the point where man will be poisoned by them.

"(6) The primary ecological change is the destruction of vegetation and the resulting ecological succession in the replacement of this vegetation."

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SECTION VI

STORAGE AND HANDLING

Herbicides are delivered in 55-gallon steel drums marked with an identifying color band. Drums may be stored in either a horizontal or vertical position. Under prolonged storage, stockpiles should be checked periodically to determine the condition of the containers and remove leakers or damaged drums. ORANGE, BLUE and WHITE are stable chemicals with a storage life of several years. The chemicals may outlast the life of the metal containers under prolonged storage exposure to tropical heat, rain, and humidity. Tests of container linings by Air Force Materials Laboratory showed most epoxy-type linings to be satisfactory; zinc and bare steel were unsatisfactory as container linings for ORANGE, BLUE and WHITE.¹⁶

Loading pumps and hoses used in transfer of herbicides from drums to storage or aircraft tanks should be kept clean and free of dirt or foreign material that may clog or impair the aircraft spray system. Transfer equipment should be flushed thoroughly with water after each period of use or in changing from one chemical to another.

Particular attention should be paid to the condition of rubber-lined transfer hoses. ORANGE causes deterioration of the rubber lining, and dislodged fragments may cause malfunctioning and leaking of the spray nozzles or check valves. Teflon or Viton seals should be used in transfer equipment and spray systems when possible.

Some difficulty has been experienced with precipitate in some lots of agent BLUE. Drums should be checked to ensure that precipitate, if present, is not pumped into the aircraft spray system.

Especially care should be taken in the change from one chemical or agent to another in loading aircraft spray tanks. The precautions to follow in loading aircraft are outlined in Table VI. Particular emphasis should be given to sequences involving BLUE and WHITE. A mixture of these two agents results in the formation of a precipitate consisting of the sodium salt of 2,4-D (component of WHITE). When a change in agents is to be made, the tanks or spray system should be filled at least half full with clean water and the system exhausted of liquid before the new agent (BLUE or WHITE) is added. In addition, when a change is made from ORANGE to the water-base-agent BLUE, it is good practice but not mandatory to flush the tank and spray system with diesel fuel followed by a clear water rinse before filling.

Care should be taken to avoid spillage of chemicals on or in aircraft. ORANGE and ORANGE II are deleterious to some painted surfaces, and any spillage or spray deposit on aircraft or painted surfaces should be flushed off with diesel fuel or other light petroleum oils, followed by a soap or detergent solution and thorough rinsing in clear water. BLUE and WHITE are water-soluble, and spillage may be removed by thorough washing with clear water.

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TABLE VI. RECOMMENDED PROCEDURES FOR FILLING AIRCRAFT DEFOLIANT TANKS CONTAINING RESIDUE OF A DIFFERENT DEFOLIANT

Residue in Tank	Agent for Fill	Procedure
WHITE	ORANGE	Agitate to blend in residual WHITE.
WHITE	BLUE	Flush thoroughly with water to prevent formation of precipitate.
BLUE	WHITE	Flush thoroughly with water to prevent formation of precipitate.
BLUE	ORANGE	Agitate to blend in residual BLUE. <u>Optional:</u> flush with water and drain.
ORANGE	WHITE	Flushing not required.
ORANGE	BLUE	Agitate to blend in residual ORANGE. <u>Optional:</u> flush with diesel fuel and/or water.

A. SAFETY PRECAUTIONS

The chemicals discussed in this manual are nontoxic to humans and animals under normal use conditions. Personnel handling the chemicals should take normal sanitary precautions to maintain personal cleanliness and to avoid skin and eye contact with the material. Contaminated clothing should be washed before re-use. Spillage on the skin or in the eyes should be rinsed copiously with clear water. Rubber and rubber products, such as shoe soles, are subject to deterioration in continued contact with ORANGE.

B. DISPOSAL OF SPILLAGE AT LOADING AND STORAGE AREAS

Loading and storage areas contaminated by excessive spillage of the chemicals ORANGE, BLUE and WHITE may be treated by repeated flushing with diesel fuel or water and diversion of the drainage into settling basins or pits for incorporation into soil, where microbial degradation and photodecomposition may occur. If possible, heavily contaminated soils or settling basins should be deep plowed to work the chemical into the soil to aid in subsequent leaching, decomposition, or deactivation.

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The three agents differ somewhat in their residual characteristics when incorporated with soil. ORANGE is decomposed fairly rapidly by soil microorganisms but is relatively resistant to photodecomposition. BLUE is rapidly adsorbed and deactivated when incorporated into soil. Runoff or flushings from equipment or storage areas containing ORANGE or BLUE should be promptly incorporated into soil of settling basins or pits for rapid dissipation.

The picloram component of WHITE is decomposed slowly by microorganisms. Dissipation of waste materials containing principally WHITE can be accomplished by prolonged surface exposure to photodecomposition in settling basins or by deep leaching in light-textured soils in restricted areas not subject to overflow on cropland.

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SECTION VII

AERIAL SPRAY SYSTEMS AND APPLICATION

A. AERIAL DISSEMINATION SYSTEMS

1. A/A45Y-1 Internal Defoliant Dispenser

The A/A45Y-1 defoliant dispenser is a modular spray system for internal carriage in cargo aircraft. It has been used only in C-123 aircraft but is adapted for use in the C-130. Currently, only UC-123K aircraft are used with the A/A45Y-1 system. Two gasoline-burning jet engines have been incorporated in this model to provide an additional source of emergency power after spray dissemination.

Essential design features of the A/A45Y-1 dispenser are:

1,000 gallon tank

20 hp gasoline engine and pump

Operator's console with pump and spray release controls

Wing booms 17 feet long and 1½ inches in diameter, extending from outboard engine nacelles toward the wing tips, with 12 check-valve nozzles regularly spaced.

Tail boom 20 feet long and 3 inches in diameter, positioned centrally near the aft cargo door, with four check-valve nozzles on each end spaced at 6-inch intervals.

Nozzles are Spraying Systems Company check-valve bodies (3/8 inch) without nozzle orifices, the spray being emitted directly from the open check valves.

Performance characteristics:

Aircraft speed	135 knots
Flight altitude	150 feet
Effective swath width	240 feet
Application rate	3 gallons/acre
Delivery rate	250 gallons/minute
Spray droplets, MMD	320 to 350 microns
Spraying time for 950 gallons	4 minutes
Length of swath	10.4 statute miles (16.7 km)

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2. UH-1B/D Helicopter Spray System (AGRINAUTICS)

The AGRINAUTICS (formerly AGAVENCO) spray unit is self-contained and is suitable for use in the Army UH-1B and UH-1D, the US Navy UH-1E and the US Air Force UH-1F helicopters. It can be installed in or removed from the aircraft in a matter of minutes because it is merely "tied down" to installed cargo shackles, and no modifications are required for its use. The sprayer was designed for the dissemination of insecticides or herbicides.

Essential design features of the Sprayer-Pesticide, Helicopter Mounted, UH-1B/D are:

- 200-gallon fiberglass tank
- Cradle or support structure 10 x 4 x 3.5 ft
- Externally mounted 6-bladed windmill pump
- Spray booms 32 feet long with positions for 56 nozzles
- Weight of system, 200 pounds empty

Performance characteristics:

Aircraft speed	50 to 90 knots
Flight altitude	50 feet
Effective swath width	100 feet
Maximum application rate	3 gallons/acre at 90 knots
Spray droplets, MMD	150 to 300 microns

The UH-1B/D system has been used extensively by the Army in small-area spray applications. Under field conditions, some difficulty has been experienced with ORANGE in softening the paint on the aircraft tail assembly and fuselage. Preventative measures include preliminary coating of the aircraft with light grease and follow-up rinsing with diesel fuel or kerosene.

3. Field Expedients

A number of "jerry-rigged" or field-expedient devices have been developed for use in helicopters for small area spraying of chemicals on perimeter defenses, helicopter landing sites, and Vietcong (VC) crop areas. These field expedients have ranged from a 55-gallon drum equipped with spray bar for temporary mounting across the skids of a UH-1B/D helicopter to large devices for a CH-47 aircraft consisting of a 400-gallon metal tank or 500-gallon collapsible fuel bladder with power-driven fuel-transfer pump and improvised boom.

As regular items of issue, such as the UH-1B/D Helicopter Spray System, become readily available, the use of field expedients may be discontinued.

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B. OPTIMAL CONDITIONS FOR AERIAL APPLICATION

The basic consideration in aerial application of liquid sprays for vegetation control is to secure maximum deposition of the delivered agent on the selected target. Exact placement of the spray on target is essential to secure full advantage of the chemical and to prevent possible damage to crops or other desirable vegetation in proximity to the target area.

The following guidelines have been developed for RANCH HAND operations with the A/A45Y-1 system:

1. Missions will be accomplished under inversion or neutral temperature conditions with air temperatures not to exceed 85 F. These conditions are usually obtained in early morning hours. Spraying under lapse conditions will result in upward movement of fine drops with consequent drift and reduction of deposit.
2. Winds should not exceed 10 mph at ground level. Lateral displacement of spray droplets as affected by a crosswind of 3 mph is shown in Table VII.
3. Spray should be released at 150 feet or lower. Spray droplets of ORANGE 100 microns in diameter require 2 minutes to fall a distance of 150 feet. Under conditions of a 9-mph crosswind, the 100-micron drop of ORANGE may be laterally displaced 1,594 feet. A 300-micron drop will be shifted 183 feet from the line of delivery (Table VIII).
4. Mass median diameter (MMD) of the spray should be coarse (300 to 350 microns) to reduce the proportion of small drops available to drift off target. Small droplets (100 microns or less) are more effective than large drops in producing herbicidal or desiccant effects. The selected size is a compromise with effectiveness to reduce drift and secure accurate placement on the target.
5. Delivery aircraft speed should be slow (130 to 135 knots) to minimize droplet breakup from impingement of the airstream on spray at the nozzle and to maintain a capability to stay on target with changes in direction. Nozzle orifice tips have been removed from the A/A45Y-1 system to maximize droplet size at this speed.
6. Flight targets should be oriented in an inwind direction as far as possible to reduce drift.
7. Spray applications should not be made during or immediately preceding heavy precipitation. ORANGE, being insoluble in water, is least affected by rainfall occurring immediately after spray application. Effective amounts of ORANGE, BLUE and WHITE will be absorbed by the foliage within 1 hour after spray deposit.

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TABLE VII. EFFECT OF SPRAY DROPLET SIZE ON SPRAY DRIFT

Droplet Diameter, microns	Type of Droplet	No. of Droplets per Square Inch at 1 Gal. of Spray per Acre	Time Required to Fall 10 ft. in Still Air	Distance Droplet Will Travel in Falling 10 Ft. in a 3-mph Breeze
0.5	Brownian particle	-	6,750 minutes	388 miles
5	Fog	9,000,000	66 minutes	3 miles
100	Mist	1,164	10 seconds	409 feet
500	Light rain	9	1.5 seconds	7 feet
1,000*	Moderate rain	-	1.0 seconds	4.7 feet

* 1,000 microns = 1/25 inch.

TABLE VIII. RATE OF FALL AND DOWNWIND DRIFT OF ORANGE FROM 150-FOOT ALTITUDE IN 3-, 6-, AND 9-MPH WINDS

Droplet Size, microns	Rate of Fall, ft/min	Time to Fall 150 ft, min	Feet of Lateral Drift While Falling 150 ft. in Crosswinds of:		
			3 MPH	6 MPH	9 MPH
50	18	8.33	2,199	4,398	6,597
70	36	4.17	1,101	2,202	3,303
100	73	2.0	538	1,056	1,594
150	164	0.91	240	480	720
200	291	0.52	137	274	411
250	456	0.33	87	174	261
300	657	0.23	61	122	183
400	1,162	0.13	34	68	102
500	1,812	0.08	21	42	63

C. SPRAY DRIFT ON DEFOLIATION MISSIONS AND PROXIMITY TO CROPS

Spray drift from defoliation missions may become a potential problem when desirable crops are in close proximity to the target. The principal factors influencing drift from spray applications are: droplet size, height of release, and atmospheric conditions, principally horizontal air

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movement. In Table VIII, data are presented for the rate of fall and amount of lateral drift of herbicide ORANGE under three crosswind velocities on release from 150-foot altitude.

Calculations for an assumed droplet spectrum for the UC-123K system with 350-micron MMD showed that 88% of the total spray volume consisted of droplets 200 microns or larger in diameter.¹⁷ This portion of the total spray delivered under a 9-mph crosswind would fall within 411 feet of the aircraft flight path, giving a ground deposit of 1.4 to 3 gallons per acre. Under the same crosswind conditions, droplets 70 microns in diameter would drift a total distance of 1 kilometer (3,303 ft) from the flight line. Again, on the basis of an assumed droplet spectrum, droplets varying from 70 to 100 microns in size would give a total deposition volume of only 0.032 gallon/acre from a single sortie. This rate of deposition of ORANGE would cause herbicidal response only on the most sensitive or susceptible crop plants. The deposition from droplets 50 microns in size would be negligible, amounting to only 0.0012 gallon/acre for a six-sortie mission.

Thus, the most unfavorable conditions of a 9-mph crosswind, a multiple-sortie mission, and spray droplets of 350 microns MMD should give no drift damage to broadleaf crops at distances greater than 1 to 2 kilometers at a maximum. Rice and other grass crops will not be affected by drift of ORANGE at distances greater than 1 kilometer.

Under the herbicide operation procedures for aerial spray applications with the UC-123K or UH-1B/D aircraft outlined in MACV Directive 525-1,¹⁸ the prescribed distances of defoliation targets from rubber plantations and crop areas provide an adequate safety factor to avoid crop damage from spray drift from defoliation missions. Strict adherence to these procedures will insure proper application on the assigned target and minimize the hazard of damage to nearby crops or rubber plantations.

In many instances of alleged crop damage due to drift, careful examination has shown the damage to have been caused by leaking nozzles or other malfunctioning of the spray system. Equipment should be carefully checked before and after each mission to prevent leaking or spray deposition on nontarget areas.

D. VOLATILITY AND CROP DAMAGE

Two of the three herbicides in use in RVN, agents BLUE and WHITE, are prepared as aqueous solutions of water-soluble solids. The active ingredients are nonvolatile, and there is no vapor hazard associated with their use.¹⁹

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In the field of vegetation control, the butyl esters of 2,4-D and 2,4,5-T in ORANGE are considered volatile. However, the vapor pressure of these components and of ORANGE is less than 1 mm of mercury at 35 C (Table IX). The physical chemist would regard ORANGE as essentially non-volatile. In the tabular data presented, the values represent the temperatures at which vapor pressure of the material equals 1 mm of mercury. A high value, such as that of butyl 2,4-D, thus represents low volatility.

TABLE IX. RELATIVE VOLATILITY OF COMMON CHEMICALS*

Substance	Temperature at which Vapor Pressure Equals 1 mm of Mercury, C
Water	-17
Butyl Alcohol	- 1
Ethyl Glycol (permanent anti-freeze)	53
Naphthalene (solid moth balls)	53
Hexachlorobenzene	114
Kerosene	120
No. 1 Fuel Oil	120
Glycerine	125
Butyl 2,4-D	147
No. 2 Fuel Oil	153

* Data from R.C. Weast (ed.), Handbook of chemistry and physics, 49th edition, Chemical Rubber Publishing Co., Cleveland, Ohio, 1968.

Because vapor pressure of ORANGE is extremely low and, under optimal conditions, approximately 97% of the spray volume from the UC-123K system is deposited on the ground or vegetation in less than one minute following release from the aircraft, it may be concluded that vapor released during droplet descent represents an extremely small percentage of the entire mass of herbicide sprayed. Thus, vapors arising during actual spray operations are not a significant source of herbicide for crop damage outside the target area. The greatest hazard of vapor damage occurs under neutral conditions and near-calm winds. For this reason, it is recommended that spray missions be carried out only under inversion conditions insofar as the tactical situation permits.

The extent of vapor release from the vegetation after spray deposit is not known. However, under lapse conditions, the vapor would rise above the canopy and be dissipated. Under inversion conditions, the vapor would be trapped within the forest canopy and further supplement the herbicidal effect from absorption of spray droplets.

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Observations of defoliation targets by competent personnel have consistently shown sharp demarcations between the sprayed swaths and adjacent unsprayed forest areas when spraying was conducted under conditions of minimal ground wind. If volatility of the sprayed herbicide were significant, the boundaries of the sprayed swaths would be obliterated due to lateral movement of vapor into the unsprayed areas under the normal daily convectional air movements. The sharp boundary zones of sprayed areas are thus indicative of a limited volatility response.

It is concluded that lateral movement of vapor from ORANGE is negligible under ordinary conditions and that volatility of ORANGE is not significant in causing damage to crops.

E. CALIBRATION PROCEDURES FOR AERIAL SPRAY SYSTEMS

Characteristics of the spray deposition pattern from aerial systems, including mass deposit (gallons per acre), swath width, MMD, and droplet spectrum, are determined by test flights on a calibration grid with selected agents under simulated operational conditions.

Test flights are made invind to provide data for effective swath width and total deposit. Crosswind flights permit determination of MMD and droplet spectrum characteristics. Flights over the calibration sampling grid should be restricted to neutral or inversion conditions with wind velocities not exceeding 3 to 8 knots, except for crosswind flights. Parameters measured during test flights include flow rate (gpm) and dissemination time to permit determination of total delivered volume. If flow meters are not incorporated in the spray system, flow rate may be determined in static or ground tests.

1. Sampling Grid

Spray deposition samples are usually collected both on Kromecote cards and on aluminum or glass plates at sampling stations placed at regular intervals in a line perpendicular to the flight path. Dye is added to the agent to permit spectrophotometric determination of deposit from the aluminum or glass plate and to aid in visual determination of drop size on the Kromecote cards.

In calibration tests conducted in 1968 with the A/A45Y-1 system,²⁰ the sampling grid consisted of three parallel lines 5,000 feet long, each row containing 297 sampling stations. The central 1,000 feet of each line had sampling stations at 5-foot intervals.

2. Mass Deposition and Droplet Spectrum

Total mass or spray deposition (in gallons per acre) is determined for each sampling station by: (1) colorimetric or spectrophotometric determinations of the dye deposit on aluminum or glass plates; (2) visual

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counts of droplets by spot sizes on Kromecote cards with appropriate conversion to droplet volume or mass by means of spread factors; or (3) visual estimate from Kromecote cards by comparison with standard cards of varying deposition rates. Graphic plots of the deposition pattern in relation to the flight path are used in determining effective swath width.

The droplet spectrum may be expressed as the number or volume of droplets by size classes over the range of droplet size. Droplet diameter data may be obtained from the Kromecote cards. Card spot diameters (in 100-micron-diameter classes) may be converted to spherical droplet diameters by use of predetermined spread factors. In the recent Eglin AFB tests,²⁰ a minimum of 75 spots were tallied for each sampling station for computations of total deposit in droplets less than 100 microns, 100 to 150 microns, and in excess of 500 microns in spherical diameter. The spread factor for ORANGE in this test ranged from 2.441 at 100 microns to 7.957 for drops 6,000 microns in diameter.

3. Mass Median Diameter (MMD)

MMD is defined as the droplet size in microns below which one-half the total recovered mass or volume of deposit occurs. It expresses the mid-point in droplet size based on volume of spray deposited. Crosswind flights that sort out droplet sizes according to distance from the flight path are useful in measurement of MMD.

Approximations of MMD may be obtained by the spot D-max method, selecting the largest drop in a measured series of 10 to 15 individuals on Kromecote cards from crosswind flights. The spherical drop D-max computed from the spot diameter by the spread factor is then used in estimating MMD by means of a conversion factor related to aircraft speed.²¹ The conversion factor varies from 2.2 for slow speeds (80 mph) to 2.5 for high-speed delivery systems (150 to 180 mph). The following formula is used:

$$\text{Estimated MMD} = \frac{\text{Spherical drop D-max}}{\text{Conversion factor}}$$

Direct calculation of MMD was obtained for data in the 1968 Eglin Air Force Base tests by computing cumulative mass deposits over the full range of droplet size classes based on actual tallies on inwind and crosswind flights.

4. Swath Width

Swath width for a specific aerial spray system, such as the A/A45Y-1, varies with several factors, such as spray altitude, droplet spectrum and MMD, inwind or crosswind conditions, etc. The most accurate determination of swath width is obtained from direct inwind releases under inversion conditions with aircraft crossing the sample grid line at right angles.

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Effective swath width is based on a minimum biologically effective deposition rate for the agent or agents. For Southeast Asia conditions, the minimum biologically effective deposition rate for ORANGE was established at 1.0 gallon/acre.²⁰ Effective swath width can be computed as the width of a continuous swath equal to or in excess of this minimum deposit level.

5. Percentage Recovery

Percentage recovery represents the relationship between the amount of spray material released from the aircraft and the amount actually deposited on the ground at the sample line less the amount lost due to drift and evaporation. In the 1968 Eglin tests, average recovery of ORANGE was 82.74% for inwind flights and 72.36% for crosswind flights.²⁰

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SECTION VIII

GROUND DISSEMINATION SYSTEMS AND APPLICATION

A. BUFFALO TURBINE

Various dissemination devices, as field expedients, have been used in RVN for control of vegetation on limited areas. The Buffalo Turbine is representative of one type of disseminator that is capable of disseminating both liquid and dry chemicals and may be obtained from agricultural supply houses in the United States. One type of unit consists of a trailer-mounted, 50- or 100-gallon stainless steel tank with agitator, pump, turbine fan and air-cooled gasoline engine. In operation, the turbine fan generates a high-volume, high-velocity airstream which is projected through a restricted orifice and will develop an air blast with a velocity up to 150 mph and a volume of 10,000 cubic feet per minute. The chemical is atomized into a fine mist when injected into this air blast.

The Buffalo Turbine is adapted for roadside spraying and applications on perimeter defenses. Application of ORANGE or BLUE may be made of undiluted chemical or of 1:1 dilutions with diesel fuel (ORANGE) or water (BLUE).

B. POWER-DRIVEN DECONTAMINATION APPARATUS (PDDA)

The PDDA is a self-contained spray system mounted on military vehicles and was designed to disseminate decontaminating chemicals to eliminate toxic agents. In the field, these units are used for many purposes, including dissemination of herbicides. Several models of these decon rigs are available in RVN, and all are adaptable for use on vegetation control problems. The larger models have pumps capable of delivering chemicals at rates of 35 to 60 gallons per minute at pressures up to 800 pounds per square inch. Delivery is through two hoses, with adjustable nozzles, located at the rear of the unit.

The PDDA units have been used effectively with available chemicals to control vegetation on minefields, perimeter defenses, roadsides, etc. For localized applications of chemical, BLUE may be diluted with 2 gallons of agent in 50 gallons of water. ORANGE may be mixed with diesel fuel at the rate of 5 gallons to 50 gallons of diesel fuel. Applications may be made at volumes of 50 to 100 gallons of spray solution per acre as required to completely wet the foliage.²³

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SECTION IX

CONDITIONS INFLUENCING EFFECTIVE USE OF HERBICIDES

A. DEFOLIANT OPERATIONS

1. Target Vegetation

Two principal types of forest are recognized in RVN: (1) upland forests, which vary from dense tropical evergreen to fairly open semi-deciduous types, and (2) lowland or mangrove forests. The basis for this practical, simplified classification is the overall response to available chemical agents.

Upland forests usually consist of an overstory or dominant canopy of trees varying in height and crown size with one or more intermediate layers of smaller trees. The overstory trees may attain heights of 60 to 125 feet in high-rainfall areas and may consist of broadleaf evergreens or seasonally deciduous species. The intermediate and understory vegetation is often complex, with hundreds of species of shrubs, bamboo, palms, vines, and small trees ranging up to 20 to 30 feet or more.

In disturbed or partially cleared upland forests, remnants of the dominant overstory may remain with a dense secondary growth of small trees, shrubs and vines. Secondary forest or scrub and bamboo may develop rapidly on abandoned cropland or areas where timber has been removed.

Response to defoliant agents in the upland type will vary with the species mixtures and the complexity of the forest cover. Species differ widely in their response or susceptibility to the systemic herbicides ORANGE and WHITE. The long-term effectiveness of the defoliant treatments will be influenced by the proportion of resistant species. With the exception of areas dominated by bamboo, upland forest vegetation can be effectively defoliated for a period of 4 to 12 months with a single application of chemical. Repeat applications may be needed to maintain long-term defoliation, particularly in multiple-canopy areas. Secondary forest or scrub with a single canopy layer may show better canopy penetration and plant kill.

Lowland or mangrove forests are of two general kinds: those that grow in standing water, usually within the limits of mean high tide, and those that grow above the tidal limits but in marshy, poorly drained areas. In either type, the trees tend to be uniform in height, varying from 25 to 65 feet. These forests have a limited number of species, and an understory or ground cover is usually lacking. Trees have prop and aerial roots that impede movement and visibility. Nipa palm, water coconut, and tall ferns may occur near canal or river channel borders.

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Mangrove forest shows excellent response to defoliation treatment with ORANGE. Single applications may give nearly complete kill so that repeat applications are not necessary. Nipa palm is generally slower in reaction; it is readily defoliated by ORANGE but not by WHITE. In general, ORANGE is preferred for defoliation in this forest type.

2. Selection of Agent

ORANGE and WHITE may be used for general long-term defoliation on forest areas in which a rapid defoliation is not required. BLUE may be used for more rapid but correspondingly short-term defoliation of woody and grass vegetation. In general, WHITE shows a slower initial defoliation response than ORANGE and a corresponding delay in rate of regrowth or replacement vegetation. Discoloration or browning of foliage sprayed with ORANGE is evident within one week after application. WHITE is slower in producing a visible plant response, requiring approximately 2 to 4 weeks for noticeable browning of tropical vegetation.

The oil-soluble (ORANGE) herbicides are more effective under moist and rainy conditions than are the water-soluble WHITE and BLUE. Oily agents are not readily washed off the foliage and penetrate waxy leaf surfaces more readily than do water-soluble agents.

Under temperate forest conditions, broadleaf deciduous forest types may be defoliated with ORANGE or WHITE. Evergreen conifer forests are more susceptible to defoliation with WHITE than ORANGE.

3. Rate of Application

Application rates of 3 gallons per acre are used for defoliation of tropical forest vegetation with agents ORANGE, WHITE and BLUE. Research tests in Thailand indicated that ORANGE was effective on secondary growth vegetation at 2.0 gallons per acre, but for general use the 3-gallon rate is recommended. Under temperate forest conditions, application rates of 1 to 1.5 gallons per acre of ORANGE may be sufficient.

No advantage was found in increasing the rate of BLUE above 9 to 12 pounds per acre for rapid defoliation in tropical forest areas (Table IV).

4. Season of Application

Agents ORANGE and WHITE are more effective as defoliants when applied during the rainy or growing season. Both chemicals are systemic herbicides and are more readily absorbed and translocated in the plant system during periods of active growth. Under RVN conditions, some of the trees become dormant and deciduous during the dry season and subsequently are less affected by these chemicals.

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Agent BLUE, as a desiccant or contact herbicide, has been found to be effective during both rainy and dry seasons. BLUE may be preferred for short-term defoliation during the dry season.

B. ANTICROP OPERATIONS

1. Target Crops

Although extensive areas of RVN are under cultivation, selected target areas are highly restricted in location and type of crop.

Upland rice grown in recent slash-and-burn areas in the highlands area constitutes one of the principal target crops. Crop control operations are not conducted in the extensive areas of paddy rice in the IV Corps or delta region.

2. Selection of Agent

Rice, corn and other cereal crops may be effectively controlled with agent BLUE.

Most broadleaf crops such as manioc, castor beans, soybeans, sweet potatoes, garden beans, cabbage, peanuts, etc., are susceptible to treatment with ORANGE (see Section IV, A, 4).

3. Rate of Application

Recommended rate of application of BLUE and ORANGE in the UC-123K system is 3 gallons per acre. This rate is considerably in excess of the amount required as a lethal dosage but is used to provide compatibility with alternative defoliation targets, which may be chosen as replacements.

For specific crop targets to be sprayed by helicopter systems, the recommended rate of BLUE or ORANGE is 1 gallon per acre. Adjustment to the normal delivery volume of 3 gallons per acre of the UH-1B/D system may be made, if desired, by dilution of ORANGE with 2 parts of diesel fuel and dilution of BLUE with 2 parts of water per unit of chemical.

The recommended rates are considerably greater than required for crop destruction or yield reduction. Effective control of rice can be obtained with 1.0 pound/acre of BLUE and of most broadleaf crops with similar rates of ORANGE. Application of BLUE at rates as low as 0.25 pound/acre on rice will significantly reduce crop yields even though the plants may remain green.

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4. Season of Application

In general, chemical applications to crops should be made during the early growth stages prior to flowering and seed or fruit production. Rice and most broadleaf crops should be treated before seed head production. Root or tuber crops, such as potatoes, sugar beets and manioc, show greatest yield reduction from application of chemicals during early vegetative growth.

C. GRASS AND TOTAL VEGETATION CONTROL

1. Target Vegetation

For base camp perimeters, minefields, and lines of communication with predominantly tall grass and woody sprout vegetation, BLUE is the preferred agent of the chemicals currently available. Repeat applications may be required at 1- to 2-month intervals to kill back regrowth.

Bulldozed or mechanically cleared areas with heavy regrowth of woody sprouts may be treated with ORANGE at the standard application rates with aerial or ground spray equipment.

Kenapon, a liquid formulation of dalapon, has received limited trial under tropical conditions and shows promise as a systemic herbicide for control of perennial grasses, such as elephant grass, wild cane, etc. Further test work is needed to provide a recommendation.

2. Rate of Application

Similar to those for defoliation, BLUE may be applied for grass control at rates of 2 to 3 gallons per acre with aerial or ground equipment. ORANGE or WHITE may be used for woody plant control at similar rates.

3. Season of Application

Similar to requirements for defoliation.

D. GENERAL RECOMMENDATIONS

A synopsis of general use recommendations for vegetation control agents in Southeast Asia is given in Table X.

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TABLE X. SYNOPSIS OF USE RECOMMENDATIONS FOR HERBICIDES IN SOUTHEAST ASIA

Type of Vegetation Control	Target Vegetation	Agent	Rate, gal/acre	Restrictions on Use
Defoliation	Upland forest	ORANGE	3	Avoid proximity to rubber and crop areas.
		WHITE	3	Avoid proximity to rubber and crop areas.
		BLUE	3	Short-term effect.
	Mangrove forest	ORANGE	3	Preferred agent.
		BLUE	3	Optional near crops.
Crop	Rice and grain crops	BLUE	3	Use undiluted in C-123 system.
			1	Dilute with 2 gallons of water for total of 3 gallons per acre in UH-1B/D system.
	Broadleaf crops	ORANGE	3	Use undiluted in C-123 system.
			1	Dilute with 2 gallons of diesel fuel for total of 3 gallons per acre in UH-1B/D system.
			3	Use undiluted in C-123 system.
Grass and Total Vegetation	Grasses	BLUE	3	Not effective on bamboo.
	Woody regrowth	ORANGE	3	More effective on sprouts 1 year or more old.

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SECTION X

SUMMARY OF PROGRAM OBJECTIVES AND RESULTS

A. TACTICAL ASPECTS OF THE DEFOLIATION PROGRAM

Tactical uses of herbicides in defoliant operations in Southeast Asia fall in two broad categories.

1. General Uses

- a. Clear vegetation along jungle roads, trails, waterways and lines of communication, thus reducing possible ambush sites.
- b. Clear vegetation to improve observations over large jungle areas, where the enemy has deployed in strength, to reveal trails, supply routes and other enemy installations.

2. Uses on Specific or Local Targets

- a. Clear vegetation from mine fields and barriers to reduce the possibility of breaching.
- b. Clear vegetation around critical friendly installations, such as ammunition dumps, supply depots, communication facilities, air defense sites, etc., to minimize enemy surprise attacks and patrol action and to reduce the requirement for local security forces.
- c. Clear vegetation and increase the visibility in established friendly fields of fire for likely avenues of enemy approach.
- d. Increase the visibility for observers in adjusting artillery fire.
- e. Defoliate woody growth on areas previously cleared by Rome plow or mechanical means.
- f. Clear large areas of dense vegetation for major construction projects and for health or sanitation reasons. Herbicides may be used to mark areas in jungle terrain where roads are to be built.

3. Results

Benefits and results of the defoliation program are expressed in the following statements excerpted from field commanders' reports and other sources:²

- a. Large area defoliation has increased vertical visibility in forests from 75 to 85%.

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b. Aids in visual reconnaissance. In defoliated areas, both USAF forward air controllers and U.S. Army aerial observers have discovered entire Viet Cong base camps that had previously been overlooked.

c. Defoliation along friendly lines of communication has exposed enemy ambush sites and denies the enemy concealed observation sites.

d. Provided improved surveillance and interdiction by fire of areas that previously offered concealment to the enemy.

e. Defoliation operations have resulted in the exposure of VC routes and storage areas to aerial observation and surveillance, and this has had a tremendous adverse effect on the enemy's activity and his freedom of movement.

f. Ground visibility has been improved from an average of 25 meters prior to defoliation to 100 meters subsequent to defoliation.

g. Observation on the ground and from the air is improved.

h. Artillery adjustment is more easily accomplished.

i. Conventional artillery fires and aerial rocket fires penetrate to the ground in defoliated areas, whereas many rounds are wasted on the canopy in heavily foliated areas.

j. Reconnaissance elements of a U.S. infantry division complained that the defoliation program denies them the needed concealment for operation.

k. In War Zone C, the number of brigades necessary to maintain US/RVN presence was reduced from seven prior to defoliation to three after defoliation.

l. In War Zone D, a requirement for a 2½-division effort planned for 1967 was partially eliminated due to the effects of defoliation.

B. TACTICAL ASPECTS OF THE CROP DESTRUCTION PROGRAM

Agents BLUE and ORANGE are used to destroy crops on areas approved by COMUSMACV and the U.S. Ambassador under policies and guidance outlined in MACV Directive 523-1.¹⁸

Crop destruction operations, aimed at denying vital foodstuffs to enemy forces, provide a definite psychological effect on these forces. Crop destruction has contributed significantly to food shortages and morale problems in enemy units. After the crops have been destroyed in a particular area, the procurement and distribution of food requires an

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increased number of enemy troops and results in considerable animosity among the local populace toward the VC and North Vietnamese Army (NVA) troops, whose presence brought about the loss.

Crop destruction programs may require that food be brought in from other areas by the VC and NVA or that they move to new positions. To prevent the necessity of moving to a new area, the VC have undertaken food preservation programs. Harvested food is covered with plastics and other material to avoid contamination by the spray. Local farmers are advised by the VC to scatter their crops and to intermix vegetable plots with rice paddies making them less vulnerable to spray operations.

Crop destruction efforts have been successful because of selective targeting procedures, and in some VC-controlled areas, VC food rations have been reduced up to half the normal amount following crop destruction operations.

C. SCOPE OF DEFOLIANT AND ANTICROP OPERATIONS IN RVN

The number of acres sprayed yearly from 1962 through 1968 for defoliation and crop destruction are given in the following table based on data furnished in MACV reports:

Year	Acres Sprayed		
	Defoliation	Crop Destruction	Total
1962	4,940	741	5,681
1963	24,700	247	24,947
1964	83,468	10,374	93,842
1965	155,610	65,949	221,559
1966	741,247	101,517	842,764
1967	1,486,446	221,312	1,707,758
1968	1,267,110	63,726	1,330,836

D. POLICY AND PROCEDURES IN OPERATIONAL EMPLOYMENT OF HERBICIDES IN RVN

The general policies, responsibilities and procedures governing the operational use of herbicides in RVN are outlined in MACV Directive 525-1.^{1a} The use of herbicides for defoliation and crop destruction is primarily a Government of Vietnam (GVN) operation that is supported by the U.S. Government. Under policy guidance established by the U.S. Defense and State Departments, COMUSMACV and the U.S. Ambassador are empowered jointly to authorize U.S. support of GVN requests for herbicide operations. General coordination of the program is given by Chemical Operations Division of J-3, MACV.

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All requests for defoliation by fixed wing aircraft and for all crop destruction originate at the district or province level. Requests approved by the Corps Senior Advisor and the Joint General Staff 202 Committee, Republic of Vietnam Armed Forces, are then processed by the Chemical Operations Division, J-3, MACV, and coordinated with 203 Committee members consisting of J-3, Psychological Operations Division, J-2, Civil Operations and Revolutionary Development Support (CORDS), USAID, JUSPAO, and the American Embassy (Fig. 1).

After final approval by the U.S. Ambassador and COMUSMACV is furnished to the JGS, a coordination meeting is held at the province capital by the Province Chief, U.S. Province and Corps Advisors, MACV Chemical Operations Division Action Officer, JGS representatives, and RANCH HAND personnel. Final details and changes in previous requests are made, and special conditions required during spray operations are established. JGS then publishes an operations order for the approved target, and priority and coordination details are provided by Chemical Operations Division to the Commander, 7th Air Force, and 12th Special Operations Squadron (SOS) for execution of the project.

A final opportunity is given to the Province Chief to approve or reject the spray mission 24 to 48 hours before the selected date of execution.

Corps commanders are delegated authority to carry out helicopter defoliation operations approved by the Province Chief and the U.S. Corps Senior Advisor. These operations are conducted in support of local base defense, maintenance of deforested areas, and on known small ambush sites along lines of communication.

Corps Senior Advisors may approve defoliation requests with surface- or ground-based equipment.

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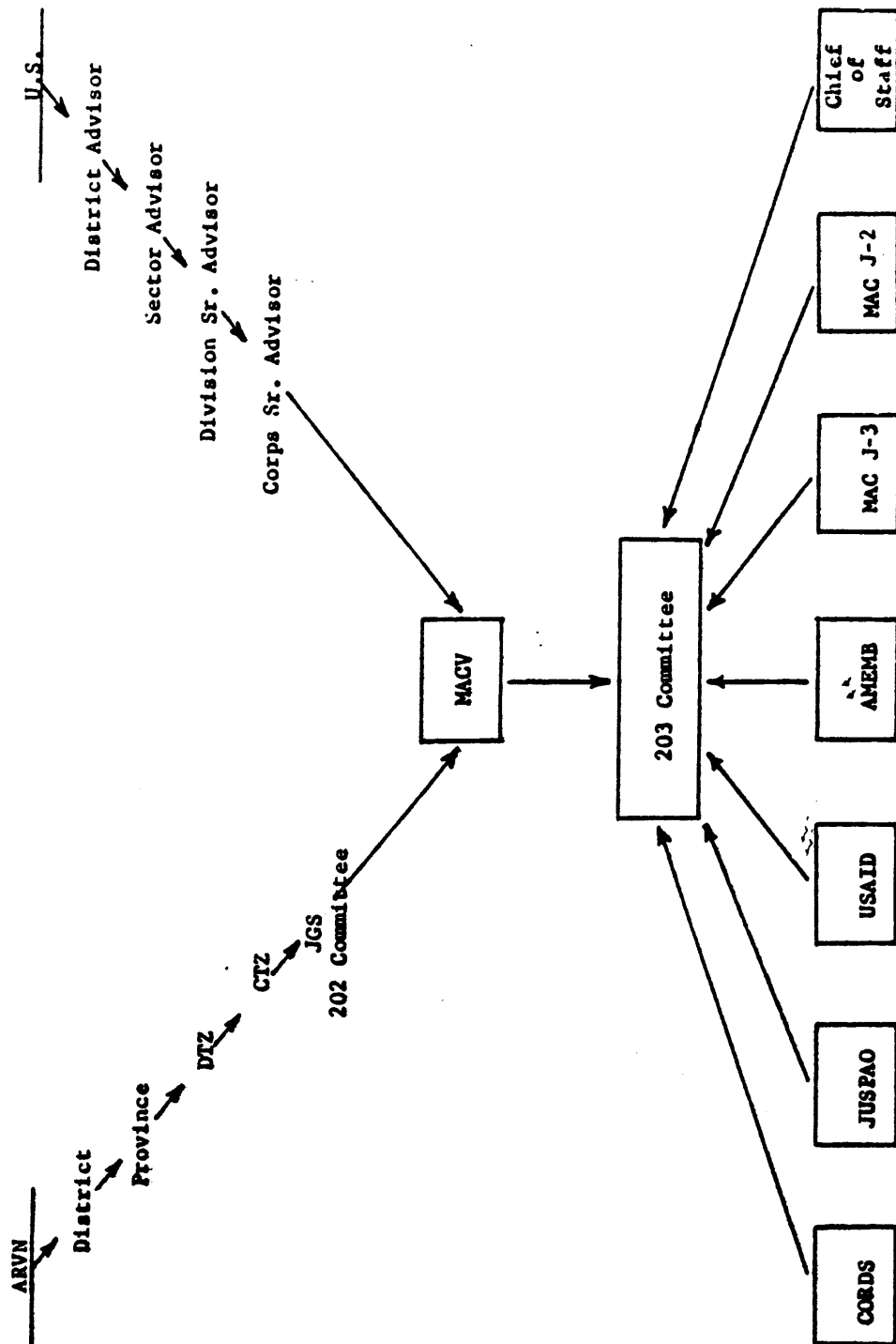



Figure 1. Schedule for Defoliation and Crop Destruction Requests in RVN.

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APPENDIX A

GLOSSARY OF TERMS

Acid equivalent: the amount of active ingredient expressed in terms of the parent acid.

Active ingredient: chemical compound in a product that is responsible for the herbicidal or desiccant effect.

Acute oral LD₅₀: the dose required to kill 50% of the test animals when given as a single dose by mouth. The dose is normally expressed as the weight (mg) of chemical per unit weight (kg) of animal.

Anticrop agent: a chemical or biological agent capable of damaging or destroying productivity of crop plants.

Contact herbicide: a herbicide that kills primarily by contact with plant tissue rather than as a result of translocation or systemic action.

Corrosion: gradual wearing away of metals and other solids by chemical reaction.

Defoliant: a chemical that causes leaf fall when applied to a plant. A true or nonherbicidal defoliant may cause defoliation without killing or seriously affecting the plant.

Desiccant: a chemical that causes dehydration or removal of moisture from plant tissue. Equivalent to contact herbicide.

Dosage: amount (in weight or volume) of active agent deposited per unit area.

Drift: see spray drift.

Formulation: a preparation containing a herbicide or chemical in a form suitable for practical use. Examples: ester, amine salt, granular, pelleted, wettable powder.

Growth regulator: an organic substance effective in minute amounts for controlling or modifying plant processes.

Herbicide: a chemical used for killing plants or modifying their normal growth. See also Contact, Nonselective, Residual, Selective, and Systemic herbicide.

Inversion (Temperature): atmospheric conditions in which the air temperature near the ground is colder than at a higher altitude.

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Lapse (Temperature): atmospheric conditions in which the air temperature decreases with elevation above ground level.

Mass median diameter (MMD): the median droplet size of a spray deposit spectrum in which 50% of the total spray volume or mass is made up of droplets larger and 50% smaller than the given median diameter. Usually expressed in micron.

Nonselective herbicide: a chemical toxic to plants in general without regard to species.

Phytotoxic: toxic to plants.

Residual herbicide: a herbicide applied to the soil, where it remains active for at least several weeks.

Selective herbicide: a chemical that is more toxic to some plant species than to others.

Soil application: application of chemical principally to soil rather than to vegetation.

Soil sterilant: a term inappropriately used for soil-applied herbicides that may temporarily prevent growth of plants. Residual herbicide is the preferred term.

Spray drift: the movement of airborne spray particles from the intended area of application.

Systemic herbicide: a herbicide that, after uptake either through roots or foliage, moves within the plant, thereby affecting parts of the plant remote from the point of application.

Surfactant (surface active agent): a material that facilitates and accentuates emulsifying, dispersing, spreading, wetting or other surface-modifying properties of liquids.

Toxicity: the quality or degree of being toxic or poisonous. Used here in the sense of a chemical being injurious or lethal to animal life. Chemicals may be rated on their mammalian toxicity in terms of the amount of material required in a single ingestion to cause a lethal effect (acute oral toxicity). Other aspects, such as cumulative ingestion, skin and eye irritation, and inhalation effects, should also be considered in rating toxicity.

Translocation: movement of food, nutrients and liquid within the plant system. Herbicides may be transported in a similar manner.

Translocated herbicide: see systemic herbicide.

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Total vegetation control: use of a herbicide (residual) to kill vegetation on noncropland where selectivity is not required.

Vapor drift: the movement of vapors from the area of application. See also spray drift.

Viscosity: the resistance of liquids to flow, measured by determining the rate of flow through a small opening.

Volatility: the tendency of a chemical to vaporize or give off fumes. The vapors may damage susceptible crops or may reduce, through loss, the effectiveness of the herbicide. Esters of 2,4-D and 2,4,5-T made from 5-carbon alcohols, or less, such as the butyl esters in ORANGE, are considered volatile. Amine salts, such as in WHITE, are considered nonvolatile. Volatility is directly related to vapor pressure.

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APPENDIX B

CANDIDATE AGENTS FOR VEGETATION CONTROL

A. SYSTEMIC HERBICIDES

1. Modified ORANGE

a. Chemical Components

The term Modified ORANGE has been given to a mixture of ORANGE and picloram proposed as an improved defoliant. Components of the mixture on a volume basis are: ORANGE, 3 parts; Tordon 40, 1 part.

b. Manufacturer

Picloram or Tordon is manufactured by Dow Chemical Co. Tordon 40 consists of the isooctyl ester of picloram.

c. Formulation & Composition

On a composition by weight basis Modified ORANGE consists of: 1 pound picloram as isooctyl ester, 3.1 pounds 2,4-D as n-butyl ester, and 3.2 pounds 2,4,5-T as n-butyl ester.

Isooctyl ester of picloram is available in the formulation Tordon 40, containing 4 pounds per gallon of picloram.

d. Characteristics

Modified ORANGE is a systemic herbicide similar in physical and chemical properties to ORANGE. It is soluble in diesel fuel but insoluble in water.

It is proposed as a broad-spectrum defoliant.

e. Uses

Limited tests of Modified ORANGE under tropical and temperate conditions show control of a broad spectrum of vegetation with longer lasting effect than ORANGE when applied at 3 gallons per acre.

f. Approximate Cost

Modified ORANGE, \$9.50 per gallon.
Tordon 40 component, \$17.00 per gallon.

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2. Dalapon (Kenapon)

a. Chemical Name

2,2-Dichloropropionic Acid

b. Manufacturer

Dow Chemical Co.

c. Formulation

Dowpon, 85% sodium salt of dalapon.

Kenapon, liquid formulation containing 5 pounds/gallon of dalapon as diethylene glycol ether.

d. Characteristics

Dalapon is a colorless liquid very soluble in water and alcohol or organic solvents.

Formulations are mildly corrosive to equipment. Sodium salt is hygroscopic.

Dalapon is low in toxicity to man and wildlife. Acute LD₅₀ for rats is 7,570 to 9,330 mg/kg.

It is absorbed by foliage and rootsystems and is readily translocated in plants. It leaches readily in soil and is rapidly decomposed by microorganisms.

e. Uses

Dalapon is a systemic herbicide specific for the control of perennial grasses. The liquid formulation, Kenapon, has been suggested for control of tropical grasses at rates of 20 to 25 pounds/acre (4 to 5 gallons/acre). Repeat treatments may be needed at 6-week or appropriate intervals to control regrowth.

The liquid formulation is suitable for aerial application. Both Kenapon and Dowpon may be used with ground spray equipment.

f. Approximate Cost

Dowpon, \$0.63 per pound.
Kenapon, \$6.10 per gallon.

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B. SOIL-APPLIED OR RESIDUAL HERBICIDES

1. Bromacil (Hyvar)

a. Chemical Name

5-Bromo-3-sec-butyl-6-methyluracil

b. Manufacturer

E.I. duPont de Nemours & Co.

Additional formulations are available from Allied Chemical Corporation, Nalco Chemical Company, and Horne-Boatright Chemical Company.

c. Formulations

Hyvar X, 80% wettable powder (duPont)

Hyvar 10P, pellets containing 10% bromacil (duPont)

Nalkil 4B (Nalco) and Urox B (Allied Chemical), liquid formulations, containing 4 pounds/gallon of bromacil.

An experimental granule containing 85% bromacil has been prepared by Diamond Shamrock Corporation.

d. Characteristics

Bromacil is an odorless white crystalline solid, soluble in water (8.5 ppm at 25 C), stable, noncorrosive, and nonvolatile.

Bromacil is relatively nontoxic to man, wildlife, and fish. Acute oral LD₅₀ for rats is 5,200 mg/kg. It presents no hazard in handling except minor skin irritation.

Bromacil is taken in by plants primarily through the root system but may enter the foliage. It is a residual herbicide, active for long periods in the soil. It acts on plants by interference with the photosynthetic process.

e. Uses

Bromacil is a broad-spectrum soil-applied herbicide effective in the control of grasses and other plants. Under temperate conditions, rates of 12 to 25 pounds/acre give effective control of most grasses. Under tropical condition, 30 pounds/acre or more may be required. Control of grasses and some woody species may be effective for one year or more.

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Hyvar X, the wettable powder formulation, is suitable for ground equipment in high-volume applications. Aerial spray applications of liquid formulations require a minimum volume of 10 gallons/acre for use rates of 30 pounds/acre of bromacil.

Bromacil should be considered for use on base-camp perimeters, mine fields, ammunition storage areas, and other sites requiring control of grasses and woody vegetation. Currently, this and other soil-applied chemicals are not authorized for use in RVN.

f. Approximate Cost

Hyvar X, \$4.50 per pound.

2. Tandex

a. Chemical Name

m-(3,3-Dimethylureido) phenyl-tert-butylcarbamate

b. Manufacturer

Niagara Chemical Division, FMC Corporation.

c. Formulations

80% wettable powder

16% granular

Other granular formulations are available on an experimental basis.

d. Characteristics

Equally effective as a foliage spray or in soil applications.

The basic chemical is a white crystalline solid, relatively soluble in water (325 ppm at 25 C), stable, noncorrosive, and nonvolatile.

Tandex is low in toxicity to all forms of animal life. Acute oral toxicity for rats is 3,000 mg/kg. It is nonirritating and presents no hazard in handling.

e. Uses

Tandex is capable of effective control of perennial grasses and broad-leaved herbaceous and woody plants at rates comparable to bromacil. Under temperate conditions, applications of 15 to 25 pounds/acre

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of Tandex have given long-term (1 year) control of perennial grass and other vegetation. Information from tropical areas is incomplete, but it appears to be equivalent to bromacil in degree and duration of vegetation control.

f. Approximate Cost

80% wettable powder formulation, \$4.30 per pound.

3. Monuron (Telvar)

a. Chemical Name

3-(p-Chlorophenyl)-1,1-dimethylurea

b. Manufacturer

E.I. duPont de Nemours & Co.

c. Formulations

Telvar, a wettable powder containing 80% monuron.

Monuron is also formulated as Urox by Allied Chemical Corporation as monuron trichloroacetate in both liquid and granular formulations.

Urox 22, granular containing 11% monuron and 11% trichloroacetic acid.

Urox Liquid Weed Killer, oil-soluble liquid concentrate containing 3 pounds/gallon of monuron trichloroacetate.

d. Characteristics

Monuron is an odorless crystalline solid, slightly soluble in water (230 ppm at 25 C), noncorrosive, stable in storage, and subject to minimal loss by photodecomposition.

Monuron is low in toxicity. Acute oral LD₅₀ to rats is 3,600 mg/kg.

Monuron is readily absorbed through the root system and is translocated upward in the xylem (woody tissue). It acts by inhibiting photosynthesis.

Monuron is absorbed by clay soils in contrast to sand so that higher use rates are required.

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e. Uses

Monuron has been used for selective weed control at low rates (1 to 5 pounds/acre) and for general vegetation control at 16 to 48 pounds/acre or more. Resistant perennial grasses may require more than 50 pounds/acre and additional repeat treatments for long-term control.

Monuron or Telvar is suitable only for ground spray application in high volumes.

Urox 22 or monuron trichloroacetate granules may be applied at rates of 200 to 300 pounds/acre of product for perennial grass and woody plant control.

f. Approximate Cost

Telvar, \$2.85 per pound

Urox Liquid, \$7.50 per gallon

Urox 22 granules, \$0.65 per pound

4. Diuron (Karmex)

a. Chemical Name

3-(3,4-Dichlorophenyl)-1,1-dimethylurea

b. Manufacturer

E.I. duPont de Nemours & Co.

c. Formulations

Karmex, a wettable powder containing 80% diuron.

Karmex DL, a liquid formulation containing 2.8 pounds/gallon of diuron.

Diuron is also formulated by Allied Chemical Corporation as a liquid oil concentrate, Urox "D", containing 3 pounds/gallon of diuron and as an 8% granular, Urox "D" granular.

d. Characteristics

Diuron is a white crystalline solid only slightly soluble in water (42 ppm at 25 C) but readily soluble in acetone and organic solvents.

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It has a low order of toxicity. Acute oral LD₅₀ for rats is 3,400 mg/kg.

Because of its low solubility, diuron has long residual action in the soil, especially under low rainfall conditions. Diuron is adsorbed by clay and organic matter to a greater extent than monuron or bromacil. Movement by leaching is least in soils high in clay or organic matter and greatest in sand. Losses are principally by microbial decomposition.

e. Uses

Diuron is effective in the control of grasses and broad-leaved herbaceous plants at rates of 16 to 48 pounds/acre. It has been used at lower rates for selective weed control.

Its high dosage requirement limits the feasibility of diuron for use in aerial application.

f. Approximate Cost

Karmex 80% watable powder, \$2.95 per pound.

C. GROWTH SUPPRESSANT CHEMICALS

1. Maleic Hydrazide

a. Chemical Name

1,2-Dihydro-3,6-pyridazinedione

b. Manufacturer

Uniroyal Chemical, Division of Uniroyal, Inc.

c. Formulations

MH 30, diethanolamine salt containing 30% maleic hydrazide

d. Characteristics

Maleic hydrazide is a crystalline solid, slightly soluble in water, forming water-soluble salts.

Maleic hydrazide is a growth-regulating chemical with herbicidal properties at high rates but inhibits growth at low or moderate rates. It is absorbed through the foliage and is translocated freely within the plant.

It is low in mammalian toxicity. Acute oral LD₅₀ for rats is 6,950 mg/kg. Concentrated amine solutions are corrosive to brass and other metals.

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e. Uses

Maleic hydrazide is a selective herbicide effective against grasses, particularly quack grass. It has been suggested for use in retardation or suppression of growth in grasses at rates of 3 to 6 pounds/acre.

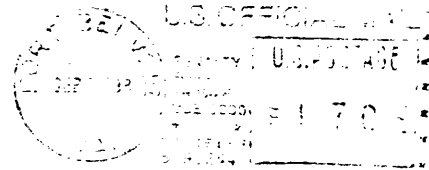
Maleic hydrazide has been used to control sprouting of root crops such as potatoes and onions, and to retard sucker growth of tobacco.

f. Approximate Cost

MH 30, \$10.00 per gallon containing 3 pounds of maleic hydrazide.

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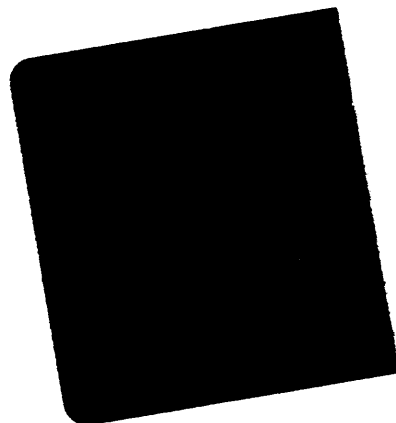
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