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TECHNICAL REPORT 79

OCONUS DEFOLIATION TEST PROGRAM

Robert A. Darrow
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July 1966

Sponsored by

Advanced Research Projects Agency
Project Agile
ARPA Order 423

UNITED STATES ARMY
BIOLOGICAL CENTER
FORT DETRICK

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U.S. ARMY BIOLOGICAL CENTER
Fort Detrick, Frederick, Maryland

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This research was supported by the
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Crops Department
BIOLOGICAL SCIENCES LABORATORY

Project ARPA Order 423 July 1966

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ABSTRACT

A test program was conducted in Thailand in 1964 and 1965 to determine the effectiveness of aerial applications of Purple, Orange, and other candidate chemical agents in defoliation of upland jungle vegetation representative of Southeast Asia on duplicate 10-acre plots. Aerial spray treatments were applied at rates of 0.5 to 3.0 gallons per acre on two test sites representing tropical dry evergreen forest and secondary forest and shrub vegetation. Applications were repeated in alternate 2- to 3-month periods to determine minimal effective rates and proper season of application.

Defoliation effectiveness was evaluated by (i) visual estimates of overall vegetation and individual species defoliation, (ii) measurements of changes in canopy obscuration by a vertical photography technique, and (iii) measurements of changes in horizontal visibility of a human-sized target at various ranges.

Data provided by these techniques were used in comparative evaluation of defoliant chemicals in relation to rate, volume, season of application, canopy penetration, and vegetation response.

DIGEST

This report presents the results of a test program to determine the effectiveness of Purple, Orange, and other candidate chemical agents in defoliation of upland forest or jungle vegetation representative of Southeast Asia. The program was conducted in Southwest Thailand by personnel from the U.S. Army Biological Center in collaboration with the ARPA Research and Development Field Unit in Thailand and the Military Research and Development Center of Thailand.

Aerial spray treatments were applied on two test sites representing a tropical dry evergreen forest, and secondary forest and shrub vegetation during the period 2 April 1964 to 4 June 1965. Spray applications were made with a Beechcraft Ten-Two (modified C-45) aircraft equipped with a 180-gallon tank, air-driven pump, and underwing boom system with diaphragm jet nozzles. Spray deposit volumes, swath pattern, and droplet sizes were obtained for each chemical mixture in the treatment series at a calibration grid near the test sites.

Applications of Purple, Orange, and Pink at rates of 0.5 to 3.0 gal/acre were made in alternate 2- to 3-month periods to determine minimal effective rates and proper season of application. Cacodylic acid and other desiccants and herbicides were evaluated in dry season and rainy season applications. Treatments were made on duplicate 10-acre plots, approximately 300 by 1500 feet.

Evaluations of defoliation response were made at weekly and monthly intervals by: (i) visual estimates of over-all vegetation and individual species defoliation, (ii) measurements of changes in canopy obscuration by a vertical photography technique, and (iii) measurement of changes in horizontal visibility of a human-sized target at distances of 10, 15, and 20 meters. Effective defoliation was considered to include ratings of 60% or more as evaluated by the visual estimate and vertical photographic techniques. In the evaluation program emphasis was given to determination of the periods of maximum and effective defoliation and the degree of defoliation response in relation to chemicals and dosage rates applied.

Results of the test program showed that:

1) Purple, Orange, Pink, Dinoxol, and Tordon were effective for long-term defoliation.

2) Cacodylic acid and diquat were effective desiccants for rapid, short-term defoliation. Maximum defoliation occurred 2 to 4 weeks after treatment.

3) Dicamba gave marginal but generally ineffective defoliation. Merphos or Folex, Endothall, tributyl phosphate, butyne diol, and amitrole were ineffective in defoliation.

4) Purple and Orange were essentially equivalent in all respects. Pink was equal to Purple or Orange at slightly lower application rates.

5) Minimum effective rate of Purple and Orange in dense forest vegetation with multiple canopy was 2.0 gal/acre (15 lb/acre acid equivalent) applied during the rainy or growing season. Applications made at this rate were effective for 4 to 6 months after treatment.

6) Minimum effective defoliation with Purple and Orange was obtained with rainy season applications of 1.5 gal/acre in forest and secondary shrub vegetation of light to moderate density and with a single canopy.

7) More complete defoliation and a longer duration of effective defoliation response was obtained in all vegetation types with applications of Purple and Orange at higher rates of application (2.5 to 3.0 gal/acre).

8) Pink gave effective defoliation at slightly lower rates than Purple or Orange. Minimum effective dosage of Pink appeared to be 1.0 to 1.25 gal/acre (8 to 10 lb/acre acid equivalent) in rainy season applications. Applications at 2.0 gal/acre gave effective defoliation for 8 to 9 months.

9) Cacodylic acid or sodium cacodylate applied in water solutions at rates of 5 to 6 lb/acre gave effective desiccation and defoliation of undisturbed forest and secondary forest and shrub vegetation in both rainy- and dry-season applications.

10) Diquat was equivalent to cacodylic acid in defoliation response at rates of 3 to 5 lb/acre. Diquat was effective only in growing-season applications.

11) Limited tests indicated that Tordon applied singly or in mixtures with 2,4-D, diquat, and Orange was highly effective on a per-pound basis but gave generally slower defoliation response than Purple or Orange.

12) The defoliation responses to aerial applications of Purple, Orange and other similar chemicals were influenced more by rate than by volume of spray solution applied. Applications of 1.0 to 1.5 gallons per acre of Purple, Orange and Pink as pure chemical gave similar defoliation responses to applications of the same amount of chemical diluted with one or more volumes of diesel fuel.

13) Minimum application volumes commensurate with good spray deposits proved to be about 1.5 gallons per acre for oil-soluble chemicals (Purple, Pink, Orange), and 2.5 to 3.0 gallons per acre for water-soluble compounds (cacodylic acid, diquat, Tordon).

14) Good penetration of sprays, and therefore, most effective defoliation responses were obtained more readily on shrubby secondary forest than in a dense, undisturbed forest with multiple canopy.

15) Optimum droplet sizes for rapid fallout and best penetration proved to be in the range of 275 to 350 microns MMD.

16) Responses to all systemic herbicides, such as Pink, Purple, Orange, Tordon, and Dinoxol were much better during the rainy season with its generally favorable soil moisture and growing conditions than during the dry season.

17) Some combinations of herbicides were found to have very promising prospects, but need more extensive evaluation in the future. The best combinations were 2.3 pounds of Tordon plus 5.3 pounds of 2,4-D and 1.2 pounds of Tordon plus 2.5 pounds of diquat. These mixtures were effective at rates of 1 to 3 pounds of Tordon per acre with the associated compound in proportion.

18) Maximum defoliation responses of 85 to 95% were recorded, but complete defoliation of all species was not obtained in any plot.

19) Visual estimates and measurements of canopy obscuration from vertical photographs gave closely comparable evaluations of defoliation effectiveness. Horizontal visibility measurements gave lower values for defoliation than visual estimates or canopy obscuration measurements. Changes in horizontal visibility due to chemical treatment reflected defoliation sustained by the shrub understory.

On the basis of evaluations completed in August 1965, the following recommendations were made:

1) For fast, short-term defoliation in light to moderate vegetation cover 5 to 6 lb/acre of cacodylic acid (7.7 to 9.2 lb/acre of Blue containing 65% active ingredient) should be applied in 2.5 to 3.0 gal/acre of spray.

In dense forest with multiple canopy, applications of cacodylic acid at 5 to 6 lb/acre may be repeated 2 to 4 weeks after initial treatment to insure penetration to lower vegetation level and to extend the period of defoliation.

Maximum effect is obtained 2 to 4 weeks after application.

Treatment may be made during rainy and dry seasons.

2) For effective defoliation and moderate duration of effect (3 to 4 months) Purple or Orange should be applied during the rainy or growing season at the rate of 1.5 to 2.0 gal/acre in vegetation with light to moderate cover and single canopy and at 2.0 to 2.5 gal/acre in dense forest with multiple canopy.

Maximum defoliation occurs 2 or 3 months after application.

In dense vegetation, repeat application 2 months following initial treatment may be needed for effective defoliation in understory vegetation and for extended defoliation effect.

3) For maximum defoliation and duration (6 months or more), Purple or Orange should be applied during the growing season at rates of 2.5 to 3.0 gal/acre, of undiluted chemical.

Heavier rates are required during the dry season for comparable defoliation response.

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I. INTRODUCTION

The defoliation of native vegetation by application of chemical defoliant agents offers a valuable tool in military tactics, particularly in counterinsurgency operations. Defoliation with the interim agent Purple has been successfully conducted on an operational basis in the Republic of Viet Nam (RVN) to reduce the incidence of ambush along principal routes of travel. Defoliation operations have been particularly effective in the mangrove vegetation along canals and the drainage systems in the RVN.[1,2] Other applications have been made in upland forest vegetation or jungle at several locations.

This report presents the results of an extensive test program conducted in Thailand to determine the effectiveness of Purple and other candidate chemical agents* in defoliation of upland forest or jungle vegetation representative of Southeast Asia. The program was conducted by personnel from the U.S. Army Biological Laboratories** at Fort Detrick, Maryland, at the request of the Advanced Research Projects Agency (ARPA) of the Department of Defense under Directive Order 423, 30 January 1963.

Military interest in the use of chemicals for defoliation of tropical and temperate vegetation was expressed as early as 1945. Since this period, a substantial body of information on chemical defoliation has been assembled by the U.S. Army Biological Laboratories through greenhouse and exploratory field tests.[3] The first extensive aerial applications of chemicals for military defoliation of forest vegetation were conducted at Camp Drum, New York in 1959.[4] They demonstrated the effectiveness of a mixture of undiluted butyl esters of 2,4-D and 2,4,5-T applied at approximately 0.75 gal/acre in the defoliation of a mixed deciduous and conifer forest. These tests served as a basis for the recommendations of Purple for operational tests in the RVN sponsored by ARPA.

In 1961 and 1962, Dr. James W. Brown of Crops Division of the U.S. Army Biological Center conducted aerial and ground spray tests with Purple and several other chemicals in the RVN area under sponsorship of ARPA.[5,6,7] Evaluations of the early operational tests of Purple led to a preliminary recommended application rate considered to be more than adequate to produce the desired results.[8]

The need for additional information on effective defoliation and the limitations on an adequate test program imposed by guerrilla warfare conditions in RVN led to the development of the present program in

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* Chemical names of Purple and other defoliants used in the program are given in Section II.

** The name of these Laboratories was changed to U.S. Army Biological Center early in 1966.

Thailand under a similar climate and with similar vegetation. Prior to the development of a test plan, joint discussions were held by ARPA and U.S. Army Biological Center representatives with personnel from the Crops Protection Research Branch of the Agricultural Research Service of U.S. Department of Agriculture in the selection of suitable chemicals and criteria for their inclusion in the proposed program. A test plan and research project outline were developed in March 1963 outlining a two-year program to be conducted by personnel from U.S. Army Biological Laboratories.[8,9]

The program was initiated in April 1963 in collaboration with the Military Research and Development Center of Thailand (MRDC), then known as Combat Development and Test Center (CDTC), and its United States component, the ARPA Research and Development Field Unit-Thailand (R&DFU-T). The defoliation test program has functioned in the ARPA R&DFU-T under the administrative guidance of the Program Manager for Environmental Research, Lieutenant Colonel W.R. Scheible, and under the technical direction of the U.S. Army Biological Center project leader. Close cooperation and guidance in relations with Thai military and government officials in the initiation and execution of the project were given by the Commanding Generals of MRDC, General Sinchai Menasuta and Air Vice Marshal Manob Suriya; and by the Thai Project Officers assigned to the defoliation test program, Colonel Niyom Surat-Bhibit, Royal Thai Army, and Captain Sonchai Chanhiran, Royal Thai Navy.

After general discussions on the organization and requirements for the project with officials of the MRDC and general reconnaissance of possible test locations, arrangements were made for the initial phases of the test program to be conducted at the Replacement Training Center of the Royal Thai Army near Pranburi, southwest of Bangkok. Final approval and authorization for the project by Thai governmental and military authorities was obtained in August 1963.

Test site preparations involving the survey and clearing of access lanes were initiated in August 1963. In late December 1963, a twin-engine Beechcraft airplane equipped with a spray distribution system was made available to ARPA R&DFU-T for primary use in the defoliation test program under ARPA Order 483. Calibrations of the airplane spray equipment and test site preparations were continued until April 1964 when the test applications were initiated. Field operation headquarters were located at Hua Hin about 21 miles (35 km) from the test sites. An aircraft maintenance shop and loading and storage facilities for chemicals were provided at the Hua Hin Airport. Technical supervision of the test program was given by military and civilian personnel on a temporary duty (TDY) basis from the U.S. Army Biological Center.*

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* Personnel participating in these trials are listed in Appendix F.

Under a revised test program on 1 November 1964, primary emphasis was given to determine minimal effective rates of Purple and its operational replacement, Orange. Secondary consideration was given to the evaluation of other defoliants. Under this test plan, treatments were limited to a single test location.

This interim report presents the evaluation data and tentative recommendations based on assessments made through September 1965 on test applications completed in June 1965. An additional report will be published in September 1966 to include further evaluations of the long-term effects through June 1966.

II. OBJECTIVES AND GENERAL SCOPE

As stated in the directive (ARPA Order 423 dated 30 January 1963), the objective of the test program was "to test and evaluate on site the activity of various phytotoxic chemicals on vegetation indigenous to Southeast Asia. Thailand has been selected as a representative location." Testing of 2,4-D and 2,4,5-T phenoxyacetic acid derivatives and cacodylic acid was requested as well as other phytotoxic chemicals.

Criteria or specifications for selection of phytotoxic chemicals to be included in the test program were developed in joint discussions by personnel from the U.S. Army Biological Center and the U.S. Department of Agriculture.

Objectives of the program as formulated in the initial test plan and research project outline of 22 March and 27 March 1963 were:

1) To determine minimal rates and volumes of Purple and component 2,4,5-T butyl esters (Pink) applied at different seasons of the year for effective defoliation and control of representative vegetation of Southeast Asia, and

2) To evaluate the effectiveness of other selected defoliants, desiccants, and herbicides applied singly or in combination mixtures at different seasons of the year on representative vegetation of Southeast Asia.

The initial test plan envisaged a series of aerial test applications of Purple, Pink, and other selected chemicals in two to four vegetation types representative of Southeast Asia, including evergreen forest, bamboo, and mangrove. A basic requirement was to secure information on minimal rates and volumes of application for effective defoliation by Purple.

After ir[illegible] ection of possible test locations and review of test plan objectives w[illegible] 'ficials of MRDC, the test program was initiated at a single locat[illegible] che Replacement Training Center of the Royal Thai Army near Pranbur[illegible] Modification of the number of test applications was made to conform t[illegible] .e area available at this location.

Review of test plan objectives and scope was undertaken after two series of test applications and a revised test plan was prepared on 1 November 1964.[10] Under this revised test program the general scope was modified to provide for comparative evaluations of Purple, Pink, and Orange, designated as an operational replacement for Purple. The test schedule called for comparisons of Purple applied at 1, 2, and 3 gal/acre and of Pink and Orange at 1 and 2 gal/acre in alternate two-month periods for the remainder of the program terminating in June 1965..

Tests of other chemicals were to be conducted in alternate periods, utilizing supplies of chemicals on hand.

Common and chemical names of the herbicides, defoliants, and desiccants used in the test program are shown in Table 1. Additional data on characteristics and cost of these chemicals are shown in Appendix A.

TABLE 1. HERBICIDES, DEFOLIANTS, AND DESICCANTS INCLUDED IN THE DEFOLIATION TEST PROGRAM

Code or Trade Name	Compound
	HERBICIDES
Purple	Mixture consisting of 50% n-butyl ester of 2,4-dichlorophenoxyacetic acid 30% n-butyl ester of 2,4,5-trichlorophenoxyacetic acid 20% iso-butyl ester of 2,4,5-trichlorophenoxyacetic acid
Orange	Mixture consisting of 50% n-butyl ester of 2,4-dichlorophenoxyacetic acid 50% n-butyl ester of 2,4,5-trichlorophenoxyacetic acid
Pink	Mixture consisting of 60% n-butyl ester 40% iso-butyl ester of 2,4,5-trichlorophenoxyacetic acid
Dinoxol	Commercial formulation consisting of 31.6% butoxy ethanol ester of 2,4-dichlorophenoxyacetic acid 30.3% butoxy ethanol ester of 2,4,5-trichlorophenoxyacetic acid
Tordon	Commercial formulation consisting of Picloram or 4-amino-3,5,6-trichloropicolinic acid, as the potassium salt
	DEFOLIANTS AND DESICCANTS
Diquat	1:1'Ethylene-2:2'dipyridylium cation
Butyne Diol	2-Butyne-1,4-diol
Merphos	Tributyl phosphorotrithioite
Folex	Tributyl phosphorotrithioite
Endothall acid	3,6-Endoxohexahydrophthalic acid
Endothall salt	Disodium-3,6-endoxohexahydrophthalic acid
Tributyl phosphate	Tributyl phosphate
Amitrole	3-Amino-1,2,4-triazole
Cacodylic acid	Dimethyl arsinic acid
Sodium cacodylate	Sodium salt of dimethyl arsinic acid
Dicamba	2-Methoxy-3,6-dichlorobenzoic acid

III. TEST LOCATION AND OPERATIONAL FACILITIES

The defoliation test program was conducted on lands of the Replacement Training Center of the Royal Thai Army (Khai Thanarat) southwest of Hua Hin in northern Prachuab Khiri Khan Province on the Kra Peninsula. The two test sites were located at a latitude of 12 degrees 20 minutes north, and a longitude of 99 degrees 50 minutes east, approximately 21 miles (35 km) from Hua Hin.

A. GENERAL CLIMATE AND VEGETATION OF TEST LOCATION

The test location is characterized by a tropical monsoon climate and a dry semi-evergreen forest similar to the climate and vegetation of much of the RVN and adjacent portions of Southeast Asia.

Climatic records from Hua Hin near the test location show the area to have a marked seasonal contrast in precipitation.[11] The rainy season starts in May and ends in December with maximum precipitation occurring in September. The dry season extends from December until early May and includes both the coolest month (December) and the hottest month (April). Temperatures in the Kra Peninsula at the test location are relatively uniform throughout the year because of low altitude and proximity to the Gulf of Siam. Mean daily maximum temperatures at Hua Hin range from 91 F in April to 85 F in December; minimum temperatures are from 75 to 70 F in April and December.[12]

The relatively low annual precipitation at Hua Hin of about 40 inches is caused, in part, by the interception of southwest monsoon moisture by the Tennasserim Mountains to the west along the Thailand-Burma border.

The general vegetation at the test location is a dry evergreen forest characteristic of the foothills of the Tennasserim Range in the provinces of Ratburi, Petchburi, and Prachuab Khiri Khan.[13] This type of forest occurs on the coastal peneplain and in the valleys of the foothill ranges in a precipitation zone of 40 to 80 inches. The forest cover is somewhat lower in stature and includes a greater proportion of deciduous trees than the tropical evergreen forest that attains maximum development on the Kra Peninsula south of Prachuab Khiri Khan and in southeast Thailand.

B. PHYSIOGRAPHY AND VEGETATION OF THE TEST SITES

Two areas herein called Test Sites I and II were delineated by the Commanding Officer of the Royal Thai Army Replacement Training Center for aerial applications of chemicals in the test program. Total treatment areas of 1400 acre (3500 rai) and 2000 acres (5000 rai) were allocated for Test Sites I and II, respectively. Maps of the test sites showing individual treatment plots are shown in Figures 1 and 2.

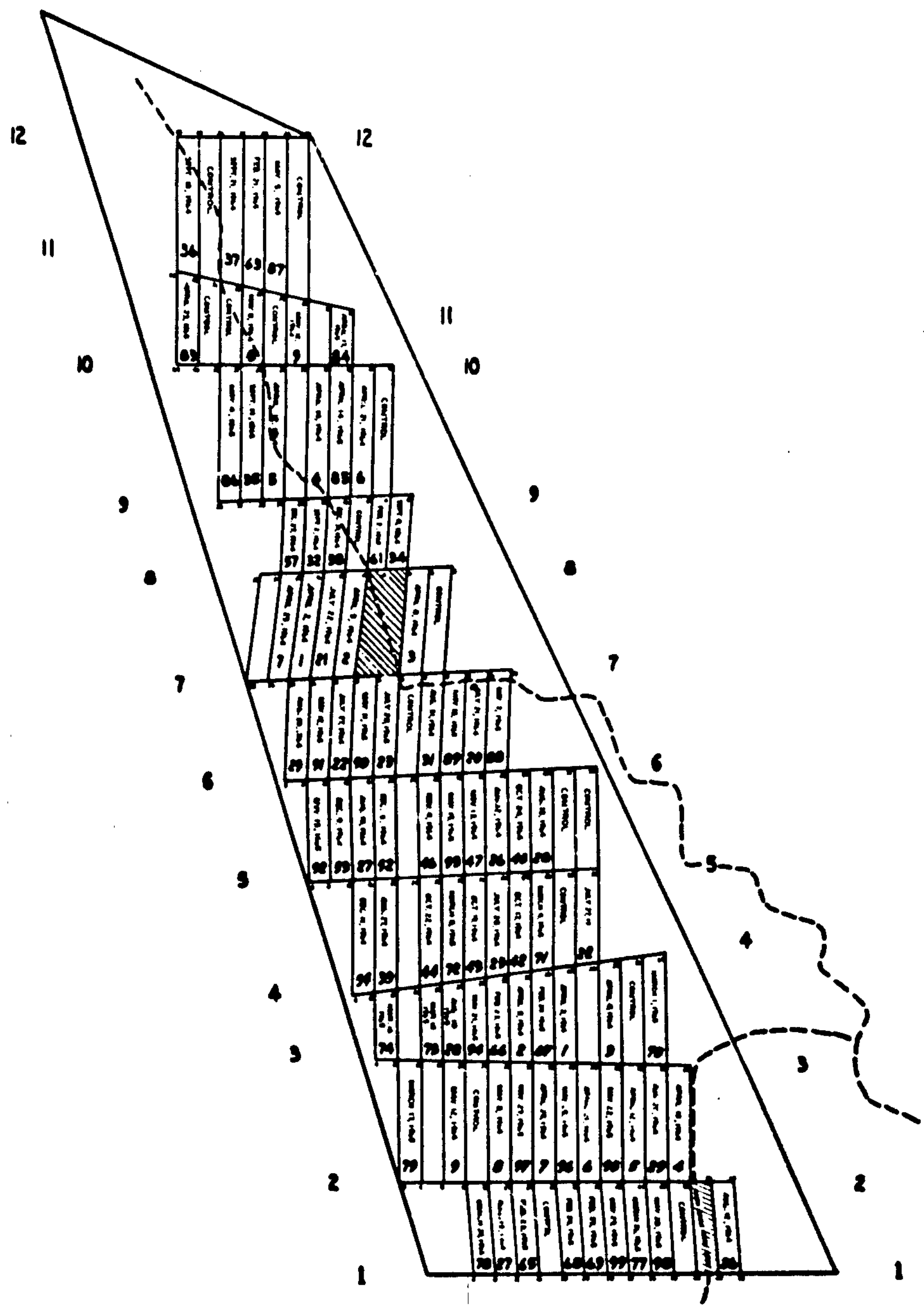


Figure 1. Test Site I Showing Access Lanes, Plot Numbers, Treatment Numbers, and Dates of Application.

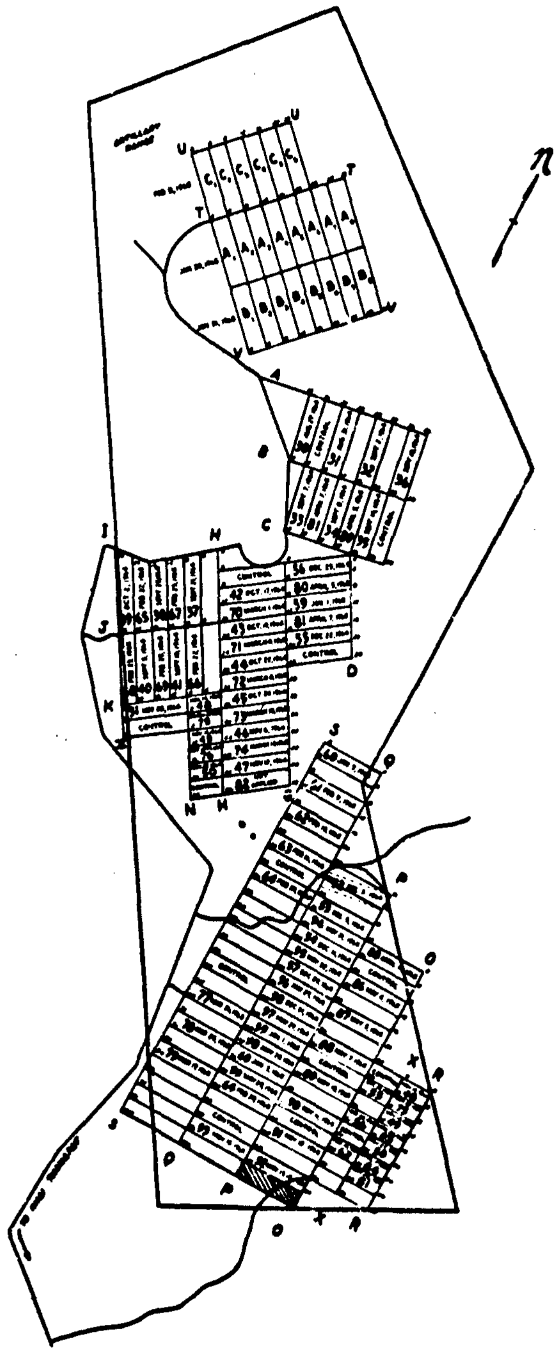


Figure 2. Test Site II Showing Access Lanes, Plot Numbers, Treatment Numbers, and Dates of Application.

1. Test Site I

Test Site I was located west of the Pranburi River in a valley bordered on the west and partially on the east by low mountainous ridges that varied from 300 to 1500 feet in height. The test area was more than one mile wide near the southern end and narrowed at the north end where the two ridges are closer together. The area was approximately 3 miles long, north to south.

The forest cover of this site was intermediate between evergreen rainforest and deciduous monsoon forest and many species characteristic of each type were found in the test area. The dominant species, however, were mostly the deciduous types of the monsoon forest, and the site has been classified as dry, semi-evergreen forest by Professor Tem Smitinand, Curator of the Forest Herbarium, Forest Products Research Division, Thai Royal Forest Department.[14]

The forest in this area was divided roughly into three layers or strata. The overstory or dominant canopy consists of rather scattered very large deciduous trees. Species in this upper level included: Mansonia gagei, Diospyros coaetanae, Lagerstroemia floribunda, L. loudonii, Millettia leucantha, Spondias mangifera, and Manilkara hexandra.

The intermediate layer, mostly of broad-leaved evergreen species, ranged from 30 to perhaps 75 or 80 feet in height. Species include principally Streblus zeylanica, Cleistanthus dasyphyllus, Celtis collinsae, Atalantia spinosa, Diospyros cauliflora, Euphorbia trigona, and Memecylon ovatum.

The understory of small trees and shrubs included Grewia sp., Mitrephora sp. and Mitragyna sp., along with smaller specimens of thorny Streblus zeylanica that form dense thickets in places.

2. Test Site II

Test Site II was located east of the Pranburi River and off the access road from the headquarters of the Replacement Training Center to the artillery ranges. The terrain at this site was mostly level with a few scattered hills.

Most of the area consisted of secondary growth of shrubby upland forest with a few remnants of the original forest of broad-leaved evergreen and deciduous trees. Principal trees in the dominant or upper canopy included: Lagerstroemia floribunda, Dialium indum, and Diospyros coaetanae. Bamboo, Bambusa arundinacea, was dominant in a portion of the secondary forest, together with Memecylon ovatum, Streblus zeylanica, Hydnocarpus ilicifolius, and Vitex quinata.

Approximately 220 plant species have been identified from the two test sites.

That the vegetation in the test areas was similar to that of the RVN is shown by the following partial list of trees and plants found in both places.[15]

TREES

Manilkara hexandra	*Ficus callosa*
Diospyros mollis	*Ficus geniculata*
Memecylon floribundum	*Bombax insigne*
Streblus asper	*Tamarindus indica*
Ficus hispida	*Albizzia myriophylum*
Ficus altissima	*Capparis micrantha*

LARGE GRASSES

Bambusa arundinacea + other bamboos
Saccharum spontaneum

SHRUBS AND VINES

Passiflora foetida
Eupatorium odoratum

A partial list of genera of trees and shrubs common to the RVN and the test location includes:

Dialium	*Hydnocarpus*	*Grewia*
Lagerstroemia	*Niebuhria*	*Mitrephora*
Millettia	*Sindora*	*Atalantia*
Spondias	*Streblus*	*Bauhinia*
Diospyros	*Vitex*	*Caesalpinia*
Euphorbia		

C. OPERATIONAL FACILITIES

Field operation headquarters were established in Hua Hin, about 21 miles (35 km) from the test sites. Hua Hin is 132 miles (212 km) southwest of Bangkok and accessible by paved road, railroad, and airplane. A residence compound was leased for office and laboratory facilities as well as lodging accommodations for resident technical personnel.

Leased vehicles and drivers were provided for travel to the test sites, airport, and for other operational requirements.

Aircraft operation and maintenance facilities were made available at the Hua Hin Airport located four miles (6 km) north of Hua Hin. Use of the airport and facilities for storage, mixing, and loading of chemicals were provided through the cooperation of the Thai Civil Aviation Department, the Ministry of Communications. A small warehouse for equipment storage was shared jointly with the International Civil Air Training Organization of the Thai Ministry of Communications that operated a flying school at the airport. An additional shed for storage of chemicals and loading equipment was provided by the Thai Border Police. Air America, Inc., contractors for the leased spray plane, constructed a storage building for aircraft maintenance, tools, and parts.

Airport authorities allotted a gravelled parking area for the spray plane and adjoining space for storage of drums of chemical, diesel fuel, aviation gasoline, and aircraft engine oil. Project personnel constructed a wooden platform near the tool shed and parking ramp for mixing operations and chemical storage.

Facilities at the airport included two gravel runways and a control tower with a two-way radio communication during daylight hours. The north-south runway was available to and operable by the spray plane throughout the entire period of calibration and test applications.

IV. TEST SITE PREPARATION

After approval of the test program and test site locations by Thai military authorities in August 1963, surveys and preparations were made for delineation of treatment plots. A basic treatment plot size of 300 by 1500 feet was selected for application of three 100-ft swaths on a 10-acre area. Treatment plots were separated by buffer zones 100 by 1500 ft as shown in Figure 3.

A. ACCESS LANES

Parallel access lanes were cleared at 1500-ft intervals delineating the ends of contiguous treatment plots and buffer zones. Lanes were cleared by groups of Thai laborers using machete-type wood axes ("meads"). The first three lanes on Test Site I were cleared to a width of 20 feet (Figure 4), requiring removal of trees up to 40 or 60 feet in height. Subsequent lanes were narrowed to a width allowing easy passage of personnel and equipment and minimal trail maintenance. Distance markers were provided at 400-ft intervals for each 300-ft-wide treatment plot and 100-ft buffer zone.

Test Site I, approximately one mile wide and three miles long, was delineated into treatment plots by 12 parallel access lanes oriented in an east-west direction. Lanes were designated by numbers 1 to 12. Lanes 1 to 7 were cleared during the period mid-August through November 1963. Lanes 8 to 12 included some previously cleared lanes, and the remainder of the test site was delineated in March 1964 into 120 possible treatment plots as shown in Figure 1.

Survey and lane clearing of Test Site II were initiated in February 1964 and continued through October 1964. An additional series of 22 plots for retreatment was established in December 1964 and January 1965. Lanes in Test Site II were designated by letters A to X. More than 150 treatment plots were made available, including several 5-acre plots 300 by 800 ft for chemicals in short supply and for evaluation of localized areas dominated by bamboo (Figure 2). Access lanes in Test Site II were oriented in several directions to provide minimal distances from the graded road marking the west boundary of the test site.

In the two test sites combined, more than 35 miles of major access lanes were cleared and maintained during the test program. Test site preparation also included the clearing and maintenance of an additional 52 miles of evaluation and camera station trails within the treated plots as described in the following paragraph. Clearing of regrowth and trail maintenance on this total 87 miles of lanes and trails was required throughout the test and evaluation period.

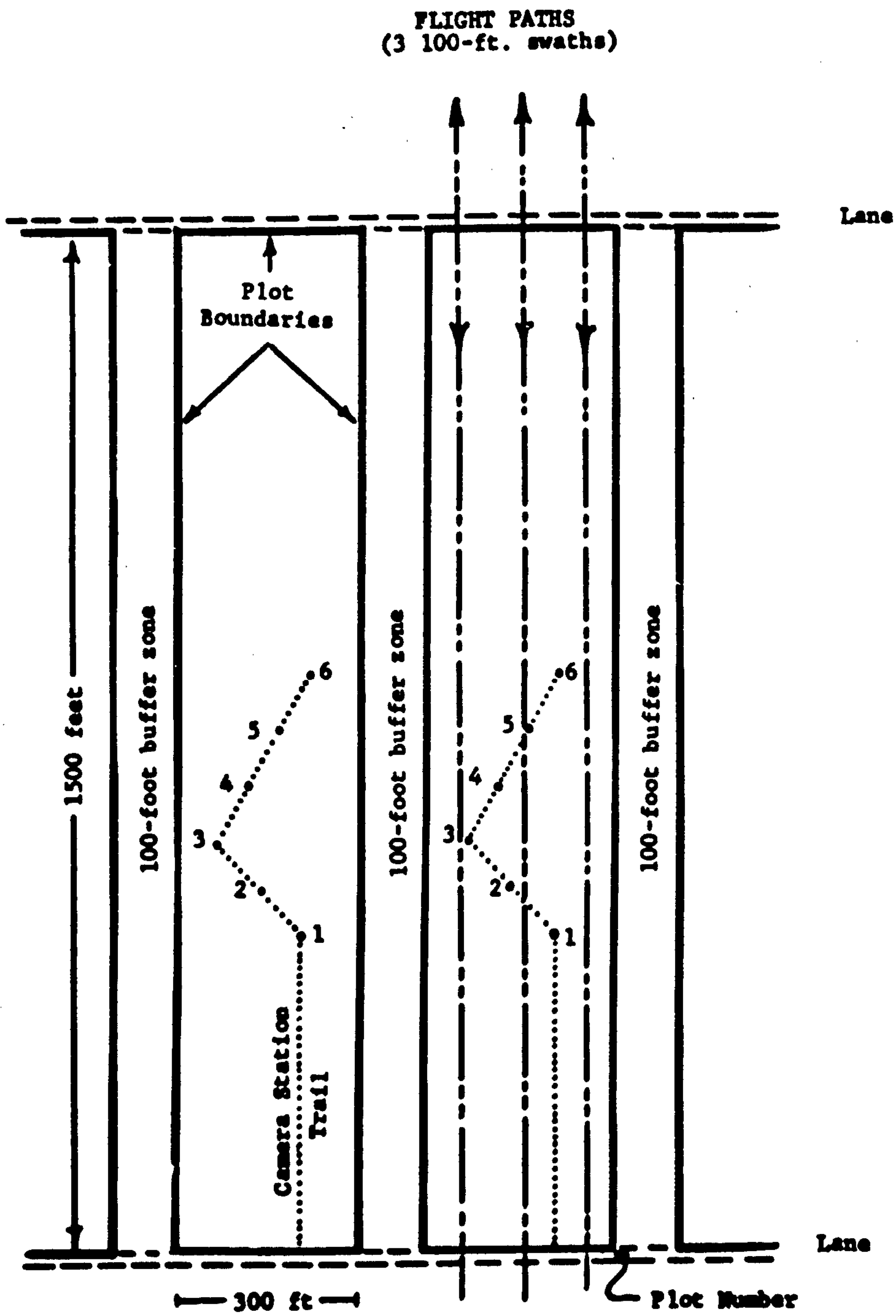


Figure 3. Plot Detail Showing Camera Stations and Treatment Pattern.

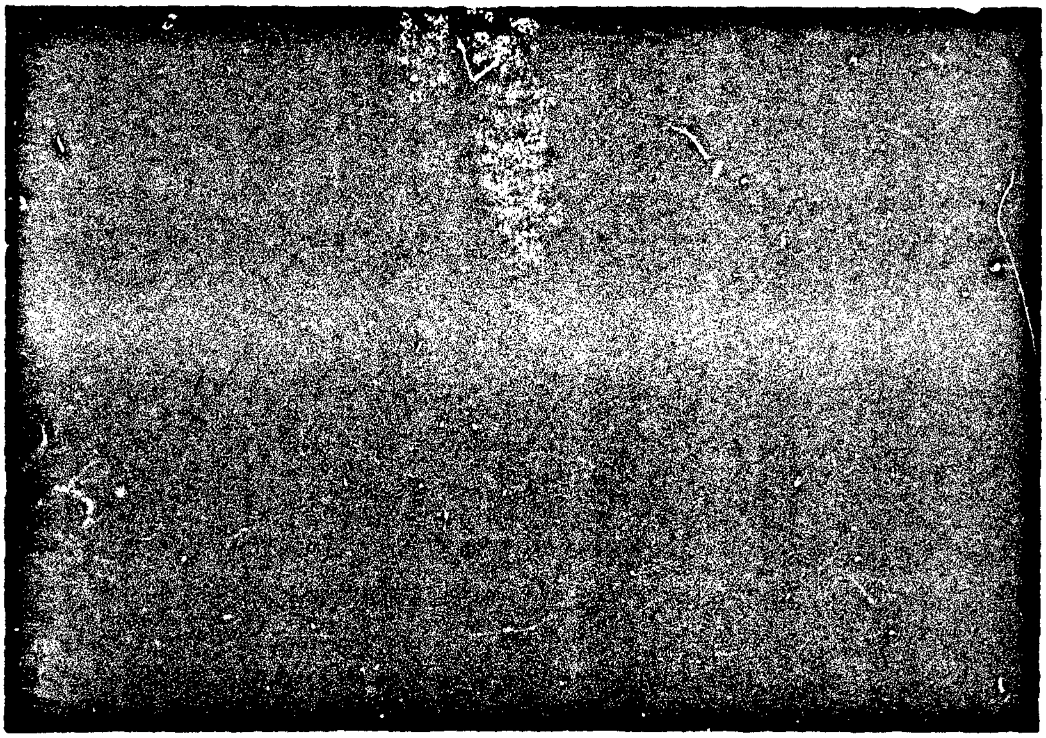


Figure 4. Access Lane at Test Site I Showing Dense Forest Vegetation.

B. EVALUATION AND CAMERA STATION TRAILS

Treatment plots were normally 300 ft wide and 1500 ft long, allowing for three contiguous 100-ft swaths 1500 ft long, as indicated by the flight paths in Figure 3. Buffer zones 100 ft wide were provided between treatment plots to allow for spray drift and overlapping of adjoining treatments. Although buffer zones were not delineated at the ends of each plot bordering the access lanes, it was recognized that overlapping of spray applications or incomplete spray deposition could occur within 200 to 300 feet on either side of the access lanes. The portion of each treatment plot selected for evaluation was therefore restricted to the center 500 ft of plot length and the central 100 ft of plot width to minimize possible overlapping and border effects.

An evaluation and camera station trail 1000 ft long was established in the central swath of each plot. Six camera stations for vertical visibility evaluation were permanently marked at 100-ft intervals with Camera Station 1 at a distance of 500 ft from the access lane at the end of the plot. From Camera Station 1 the trail was offset from the center line 30 degrees left for a distance of 200 ft and 20 degrees right for the remaining 300 ft to provide sampling stations across the central 100-ft swath.

V. AERIAL SPRAY EQUIPMENT

Lease arrangements were made in August 1963 by the ARPA R&DFU-T with Air America, Inc., for services of a twin-engine Beechcraft Ten-Two (modified C-45) equipped with a spray distribution system for use in the defoliation test program. Spray equipment was installed in the contract plane at Bakersfield, California, by French Aviation Company based on specifications mutually agreed upon by U.S. Army Biological Center and Air America, Inc. A brief flight test of the equipment was made on 16 October 1963 in the presence of personnel from U.S. Army Biological Center. Minor modifications were suggested to improve the efficiency of the distribution system for research applications.

The plane and equipment were then ferried OCONUS for additional modification prior to delivery in Bangkok, Thailand, on 17 December 1963. The plane was made available to the defoliation program in late December for flight tests and calibration.

The spray distribution system consisted essentially of underwing booms fitted with ¼-inch diaphragm-jet nozzles at 6-inch spacing, an air-driven pump, and a 180-gallon stainless steel tank. The distribution system was designed for operation at pressures of 10 or 15 to 60 psi with delivery rates of 20 to 200 gallons per minute. Deposition rates of 0.5 to 6.0 gallons per acre were possible at flight speeds of 100 knots (Figure 5).

Details and specifications of the equipment are given in Appendix B.

The spray aircraft was stationed at the Hua Hin Airport during the entire period of calibration and test application. The Air America pilot, John D. Herceg, worked closely with project personnel from U.S. Army Biological Center during the entire calibration and test application period. Two Air America aircraft mechanics were assigned to the project for the same period and provided excellent support and cooperation in the test operations, particularly in supervision of the preparation and loading of chemical spray solutions.

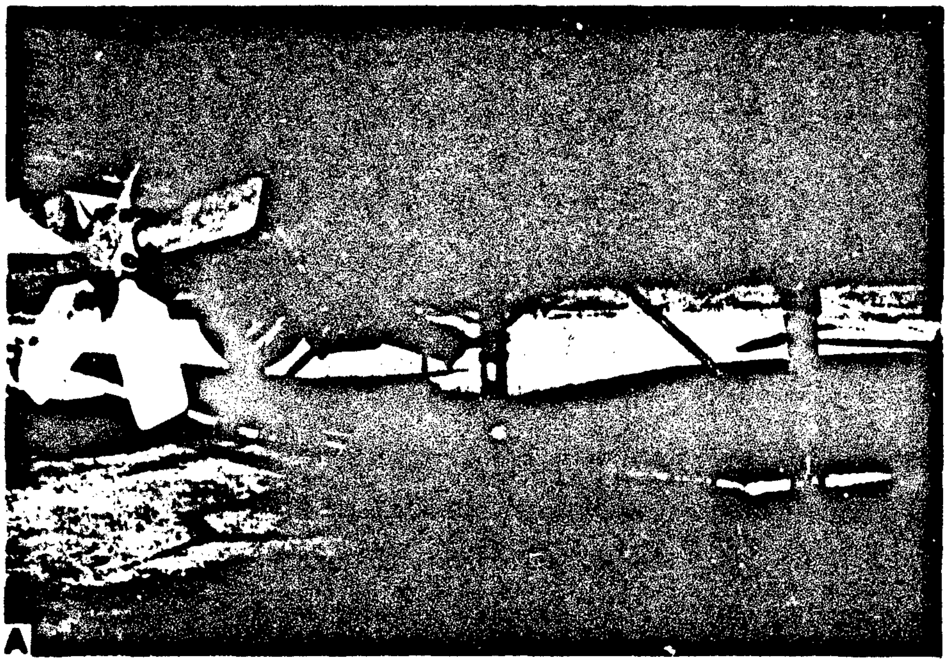


Figure 5. Boom System and Air-Driven Pump under Fuselage.
A. Front view showing pump and central section of boom under fuselage.
B. Side view of wing and central fuselage sections of boom showing nozzle placement.

VI. CALIBRATION OF SPRAY DISTRIBUTION SYSTEM

A. PRETREATMENT CALIBRATION

1. Static Flow Tests

The aircraft spray system was calibrated during stationary tests at Don Muang Airport in Bangkok to establish generalized flow rates of water and diesel fuel. Flow rates were obtained by measuring the amounts of spray delivered over specified time periods for various groupings of nozzles, nozzle orifices, and pressures.

After transfer of the plane to operational headquarters at the Hua Hin Airport, static flow tests were conducted with Purple and Pink in 1:1 or 1:2 dilutions with diesel fuel or with the pure chemical. Flow rates were also determined on water solutions of butyne diol as a representative of the water-soluble chemicals.

Flow-rate information obtained in these tests was used to select nozzle spacings and pressures for desired deposit rates with various chemical solutions and mixtures.

2. Flight Calibrations

Preliminary flight tests with diesel fuel were calibrated in early February at the Hua Hin Airport. Inwind flights were made at heights of 50 to 75 feet over the north-south runway. Spray deposit patterns were secured on oil-sensitive dye cards placed at 10-ft intervals on a 540-ft line crossing the runway.

A calibration grid was later developed at the same location to permit inwind flights in any direction. This grid consisted of four sampling lines 540 ft long with a common midpoint. Flight tests were made with diesel fuel containing red dye, and spray deposit patterns were colorimetrically determined with a Bausch and Lomb Spectronic 20 spectrophotometer.

These preliminary tests of boom configuration showed that nozzles equally spaced for full boom length produced a bimodal deposit pattern in a swath approximately 150 ft wide.

Subsequent modifications in which nozzles were restricted to inboard positions behind the engine nacelles gave approximate 100-ft swath widths but retained the bimodal pattern. Flight tests in which 10- to 15-degree flaps were used during spray application gave a suitable uniform deposition pattern with a swath width of 100 to 120 feet.

B. CALIBRATION DURING TEST APPLICATION PERIOD

In March 1964 calibration operations were moved to a new grid adjacent to the test sites. The grid was operated throughout the test application period to provide information on spray deposit rates for the boom and nozzle configurations and spray mixtures used in each treatment. From two to five flights were calibrated concurrently with each treatment. Additional calibrations were occasionally required prior to treatment with new chemicals or solutions for which data were lacking on flow-rate characteristics.

The grid was located on a rifle range on the Replacement Training Center in a cleared area 1000 by 2500 feet. Four grid lines, each 600 ft long and with a common midpoint, were delineated by 3-foot-high stakes at 10-foot intervals. Each stake was capped by a metal-rubber clip to permit attachment of a pair of 6- by 6-inch aluminum or stainless steel plates for collection of spray deposit.

During calibration flights, spray deposit patterns were obtained on the selected grid line on two series of plates (Figure 6). White Kromecote cards were mounted on one set of plates for a visual check of spray deposit pattern and for determination of mass median diameter of spray droplets. The other series of plates was used to determine spray deposit rates by the acetone wash and colorimetric technique, as described in Appendix C.

A meteorological station at the grid included a hygrothermograph, a three-element thermistor for securing temperature readings at ground level and flight altitude, and a Model L Belfort anemometer with direction and velocity transmitter mounted on a 50-ft tower (Figure 7). The anemometer was equipped with a supplemental velocity indicator calibrated to read wind velocities up to 10 miles per hour to the nearest 0.1 mile (Figure 8). Data were recorded at the time of each calibration flight on (i) wind direction and velocity at flight altitude (50 or 35 feet), (ii) air temperature at ground level and at flight altitude, and (iii) relative humidity.

Supplemental observations were made of wind direction and velocity at tree top height at one or two locations in the test sites (Figure 9). Readings were taken at 5-minute intervals by an observer stationed at the test site location during the time of plot treatment and calibration. Concurrent readings taken at the calibration grid permitted comparisons of grid and test site conditions.

Calibration operations and subsequent laboratory determinations of spray deposit rates were carried out by a crew of three to five Thai workers under the direction of a supervisor from U.S. Army Biological Center military personnel.

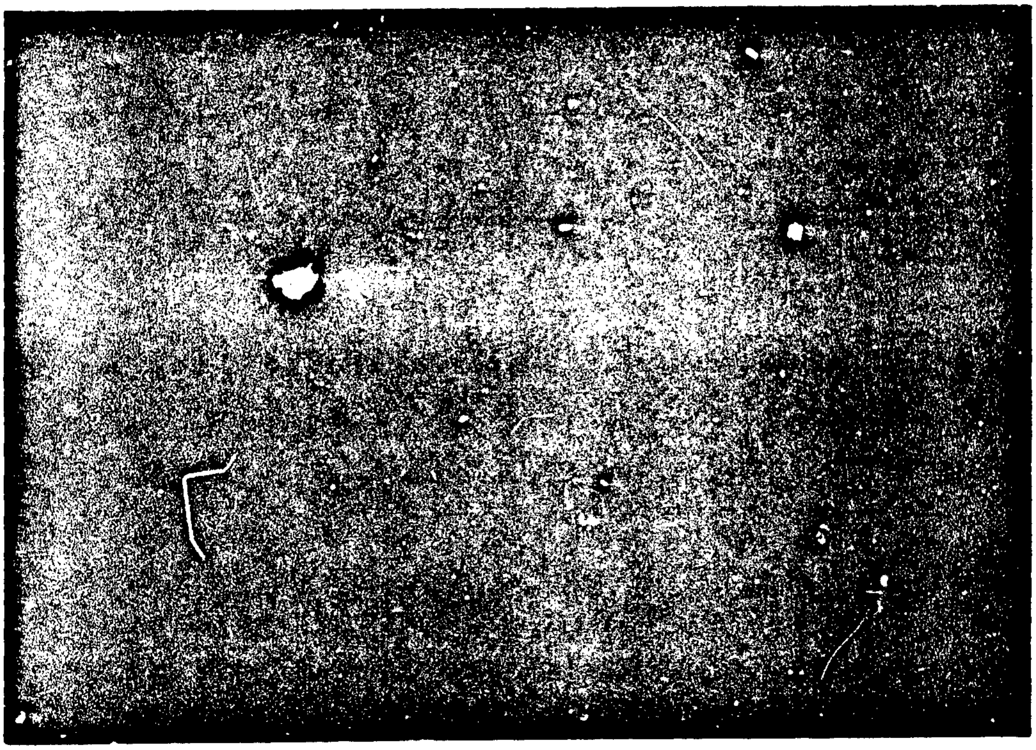


Figure 6. Grid Crew Removing Deposit Plates from Collection Stations.

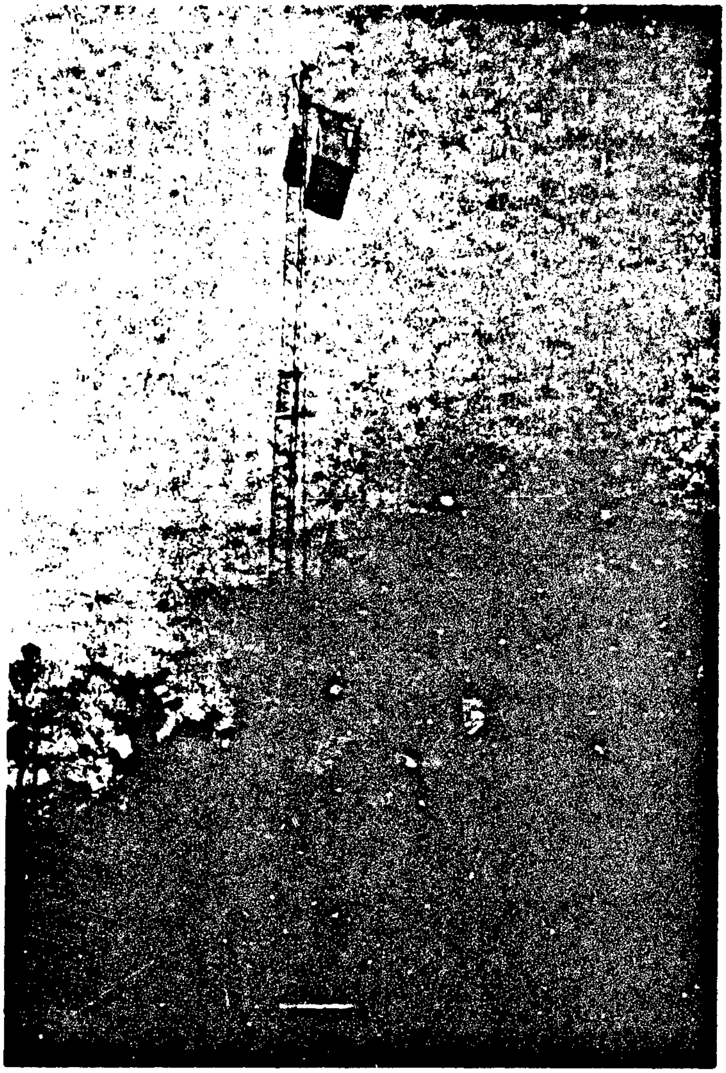


Figure 7. Telescoping Meteorological Tower at Grid Area for Obtaining Wind Direction and Velocity Measurements at the Spray Altitude.

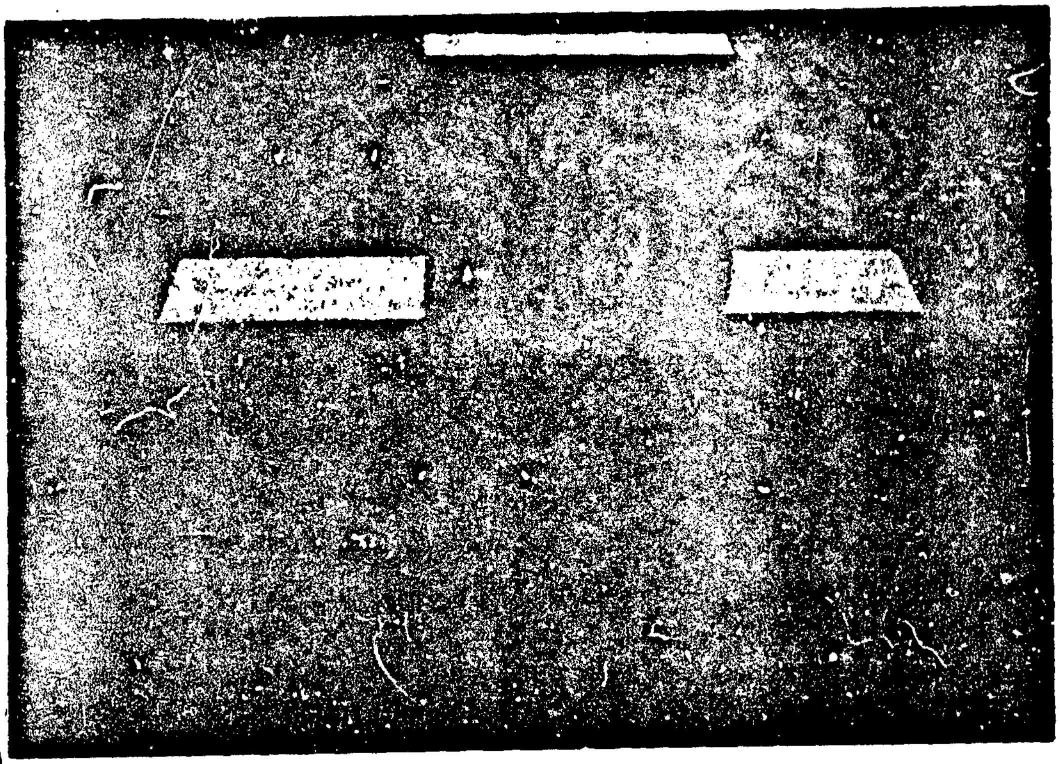


Figure 8. Anemometer Console for Wind Direction and Velocity Readings. Milliammeter at top registers wind velocity up to 10 mph to the nearest 0.1 mph.

Figure 9. Supplemental Weather Station at Test Site I.
Anemometer mounted above tree canopy.

VII. VEGETATION INVENTORY

Prior to test application, a vegetation inventory was taken on each treatment plot to provide information on vegetational composition and structure. The inventories were taken by Thai foresters of the Environmental Research group of the ARPA R&DFU-T under the direction of Lieutenant Colonel W.R. Scheible. Personnel conducting the inventories were trained to identify and recognize native trees and shrubs of the test location.

The inventory on each treatment plot consisted of: (i) a list of species in the dominant canopy and intermediate tree, shrub, and ground-cover layers for individual 100-ft segments of the central 500-ft transect; (ii) tallies of the numbers of individual plants of each tree or shrub tagged or marked for future recognition along the 500-ft belt transect; and (iii) a chart map of the individual trees and shrubs located within a 20- to 30-ft radius of each of the six camera stations.

A code number was assigned to each species for convenience in marking individuals for future recognition in evaluation of treatment response and in tabulations of vegetation inventory. Identification and marking of individual trees or shrubs along the evaluation trail by the inventory team thus facilitated later evaluations of species response by personnel from U.S. Army Biological Center, regardless of their lack of familiarity with Thailand vegetation or plant identification.

More than 220 plant species were recorded from the test site area of which 35 to 50 were frequently encountered on the tallies.

Data on species composition were compiled for each treatment plot and for the two test sites. Composition was expressed as abundance on the basis of numbers of tallied individuals of each species in each plot combined with the numbers of individuals charted on the camera-station diagrams. Percentage composition data were based on the proportion of individuals of a species to the total number of individuals tallied in each plot or in the total test site. Frequency percentages were calculated for each species on the basis of proportion of plots in each test site in which the species occurred. Data on species composition and frequency (30% or more only) for the two test sites are shown in Table 2. Species are segregated on the basis of occurrence in the dominant, intermediate, and shrub layers. A complete tabulation of species will be presented in a later report.

TABLE 2. PER CENT COMPOSITION AND FREQUENCY OF PRINCIPAL WOODY SPECIES IN THE DOMINANT, INTERMEDIATE, AND SHRUB LAYERS OF TEST SITES I AND II

Code No. and Species	Test Site I		Test Site II	
	% Composition	Frequency	% Composition	Frequency
Dominant Layer				
60 *Lagerstroemia floribunda*	0.2	86	4.9	96
49 *Mansonia gagei*	4.6	95	0.4	37
40 *Diospyros castanea*	0.7	81	1.2	68
70 *Millettia leucantha*	+[a]	75	+	27
115 *Dialium indum*	+	23	0.9	74
42 *Antheroporum pierrei*	1.9	72	+	4
37 *Diospyros mollis*	+	67	+	46
61 *Lagerstroemia loudonii*	0.3	64	+	34
86 *Spondias mangifera*	+	35	+	66
65 *Manilkara hexandra*	0.6	61	+	39
39 *Diospyros curranii*	+	49	+	39
47 *Garuga pinnata*	+	37	0.5	47
15 *Bambusa arundinacea*	-[b]	-	9.0	37
35 *Grewia elatostemoides*	+	4	1.5	29
Subtotal: composition	8.3		18.4	
Intermediate Layer				
91 *Streblus zeylanica*	45.0	100	9.5	22
101 *Cleistanthus dasyphyllus*	28.0	95	0.4	21
29 *Celtis collinsae*	0.7	92	0.2	40
53 *Hydnocarpus ilicifolius*	0.4	31	4.3	80
99 *Vitex quinata*	0.3	90	2.8	80
9 *Atalantia spinosa*	0.6	77	0.4	35
38 *Diospyros pauciflora*	1.2	76	+	45
44 *Euphorbia trigona*	3.2	75	0.6	26
78 *Phyllanthus* sp.	+	71	2.2	59
73 *Niebuhria siamensis*	+	48	+	72
66 *Memecylon ovatum*	6.9	66	12.1	48
50 *Grewia tomentosa*	+	18	3.4	66
71 *Mitrephora keithii*	0.9	64	+	2
86 *Sindora maritima*	+	5	0.6	62
75 *Olea maritima*	0.5	10	3.6	37
137 *Phyllanthus emblica*	+	3	0.8	27
Subtotal: composition	87.7		40.7	
Shrub Layer				
19 *Cleistanthus* sp.	+	19	16.2	95
11 *Acacia comosa*	+	46	14.5	91
22 [illegible]	+	33	+	91
25 *Capparis thorelii*	+	38	0.7	90
90 *Ventilago calyculata*	0.3	87	+	55
34 [illegible] *brachiata*	+	27	3.2	83
102 *Zizyphus oenoplia*	+	20	+	64
85 [illegible] *pentandra*	0.4	28	0.5	63
55 *Jasminum* sp.	+	14	+	51
125 *Euonymus cochinchinensis*	+	-	+	37
51 *Hiptage* sp.	+	36	+	18
2 [illegible] *collinsae*	+	22	+	33
63 *Tarenna longifolia*	+	3	+	32
14 *Atalantia scandens*	+	28	+	31
81 *Combretum* [illegible]	+	12	1.6	30
Subtotal: composition	0.7		36.5	
Total % Composition	96.7		95.6	

a. Trace.
b. None.

Inventory data show rather marked differences in the species composition and frequency on the two test sites, although most species were found on both sites. *Mansonia gagei* and *Antheroporum pierrei* were two of the six principal dominants on Test Site I. *Bambusa arundinacea* (bamboo) and *Lagerstroemia floribunda* were most abundant as dominants on Test Site II. On Test Site I *Streblus zeylanica* and *Cleistanthus dasyphyllus* comprised 73% of the composition of the intermediate strata. On Test Site II several other species were important components of the intermediate layer, including: *Memecylon ovatum*, 12.1%; *Hydnocarpus ilicifolius*, 4.3%; *Grewia tomentosa*, 3.4%; and *Olea maritima*, 3.6%. The shrub layer in Test Site I had no predominating species but on Test Site II *Cleistanthus* sp. and *Acacia comosa* comprised more than 30% of this layer.

Specimens of all woody species encountered were collected at the test sites and identified principally by Dr. Tem Smitinand, Forest Botanist of the Royal Forestry Department, with the collaboration of other botanists of Kasetsart and Chulalongkorn Universities. Certain plant specimens were verified and identified at the Singapore Botanical Garden Herbarium and at Kew Gardens Herbarium in London, England.

VIII. TREATMENT APPLICATION

A. PLOT SELECTION

Treatments were made on duplicate plots generally selected from the two test sites. Within the test site adjacent alternate plots were selected for rate or volume comparisons of the same chemical. Small-area plot tests and treatments on bamboo-dominated vegetation were limited to Test Site II; replicate plots of these treatments were selected from different portions of the site.

B. MARKING OF PLOTS FOR AERIAL SPRAY APPLICATION

The relative size and close proximity of test plots required a precise method for aerial location of the plots selected for treatment and for delineation of flight paths for the pilot in making spray applications at flying heights of 35 to 50 feet above the forest canopy. A flag or panel marking system was developed that satisfied these requirements (Figure 10).

Flags were erected in the tops of the tallest trees nearest the four extremities of the outer swaths to be treated. The pilot was thus able to line up flight paths on the pairs of flags marking the ends of the 1500-ft swaths and to fly midway between the pairs of end flags for the remaining central swath (Figure 3).

Marker trees were selected so that flags would be clearly visible to the pilot from either direction on the flight path when approaching at spraying height. Distances were measured from the selected flag trees to the correct positions marking the flight paths (200 ft apart). A map of corrected flight paths in relation to the flag positions was provided for pilot guidance at the time of test application.

Flags consisted of sets of three triangular cloth panels mounted at the ends of 18-foot steel tubing (Figure 11). The panels were supported by collapsible arms or braces for convenience in raising and lowering the flag through the tree canopy. When expanded, the vertically oriented panels presented a diamond-shaped surface, 6 by 6 ft, visible to the pilot from any direction.

Flags were erected by expert tree climbers from the Thai lane-clearing crews who exhibited considerable dexterity in positioning the flags in the tops of trees ranging in height from 30 or 40 to more than 100 ft.

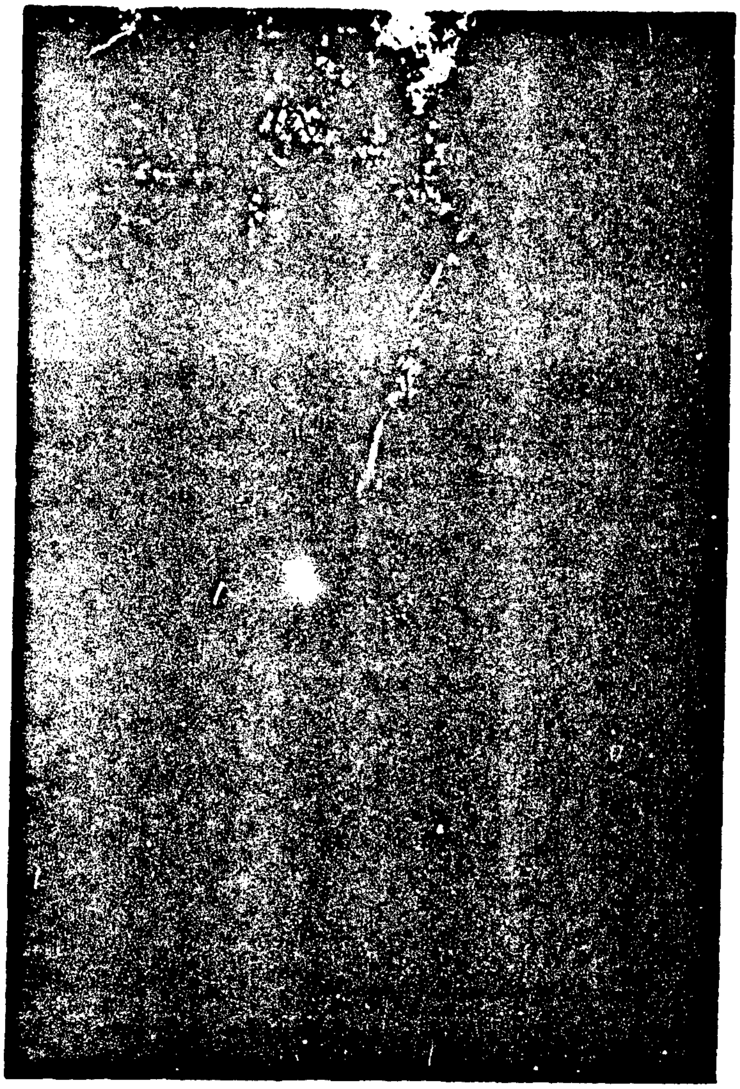


Figure 10. Crew Raising Plot-Marking Flag into Position Above Upper Canopy.

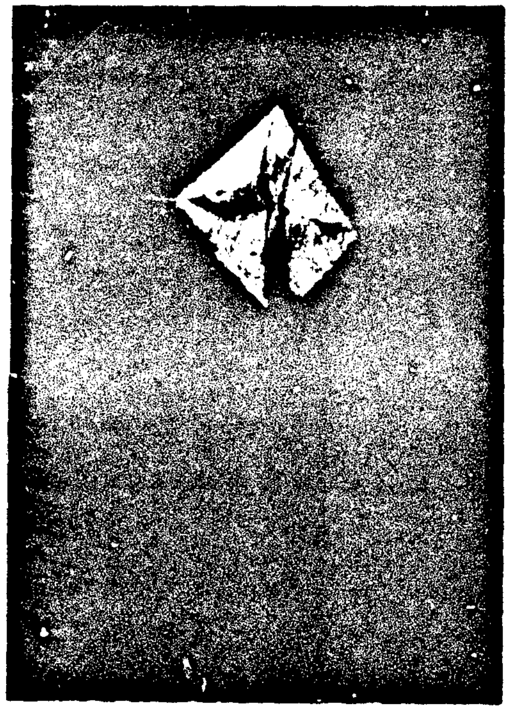


Figure 11. Plot-Marking Flag in Position Above Highest Canopy Level.

Beginning in December 1964, the positions of three of the six camera stations were marked by yellow flags prior to treatment in addition to marking the treatment-plot corners. This procedure permitted an aerial location check to insure that the camera station and evaluation trail were entirely within the area to be treated and would receive full spray coverage. Kromecote cards were exposed at each camera station for a visual check on spray penetration of the forest canopy following treatment.

C. PREPARATION AND LOADING OF CHEMICAL SPRAY SOLUTIONS

Prior to application, a chemical loading sheet was prepared with the calculated volume and composition of the spray solution for the specified treatment.

Total volume requirements for a specified test application were based on:

1) Volume needed for plot application
2) Adjustment for estimated deposit recovery
3) Volume needed for grid passes
4) Tank reserve, 30 gal
5) Boom allowance, 5 gal

For example, a specified treatment with 100% Purple was applied to obtain a deposit volume of 2.0 gal/acre. A recovery of 80% necessitated 2.5 gal/acre released from aircraft. The following tank volumes were required for the entire flight:

55 gal for 22 acres coverage
30 gal for grid passes
30 gal for tank reserve
5 gal for boom allowance

120 gal - total volume requirement

The amount of chemical required for a test application was calculated on the basis of desired deposit rate of active ingredient or acid equivalent of the material to be sprayed. Calculations took into account the purity or concentration of active ingredient in the formulated product as well as the percentage recovery volume.

For example, cacodylic acid containing 65% active ingredient was sprayed at a deposit rate of 2.5 lb/acre and a deposit volume of 2.0 gal/acre at an estimated recovery rate of 70%. The amount of cacodylic acid product required was 2.5 lb divided by 0.65 or 3.85 lb for each 2.0 gal of prepared spray mixture. To obtain a deposit volume of 2.0 gal/acre at 70% recovery, a spray delivery rate of 2.0 divided by 0.70 or 2.8 gal/acre was required. Total volume and chemical requirements were calculated as in the previous example.

In addition to calculation of total volume and chemical requirements, the proper nozzle configuration and tank pressure required to deliver the specified spray volume was determined from previous calibrations. Thus, at 100 knots' flying speed and with a swath width of 100 feet, the aircraft covered 23 acres per minute. The total nozzle flow rate required in the example with cacodylic acid was 2.8 gal/acre x 23 acres per minute or 65 gal per minute.

This information was then used by the airport crew, supervised by a technician from the U.S. Army Biological Center to measure the various components of the spray mixture and prepare them for loading into the aircraft tank.

Specified amounts of dye, usually DuPont oil-soluble red or rhodamine blue, were added to the spray mixture to determine spray deposit in grid calibrations as discussed in Appendix C.

Spray-mixture components were mixed in open-topped 55-gallon drums with hand paddles (Figure 12). The spray solution was usually prepared on the afternoon preceding the application date and loaded with a gasoline-driven centrifugal pump and oil-resistant hoses in the predawn hours just before take-off.

Gloves and face masks were used as needed to avoid skin irritation arising from prolonged contact with certain of the test materials. A Thai aircraft mechanic indoctrinated in appropriate safety precautions supervised the ground crew.

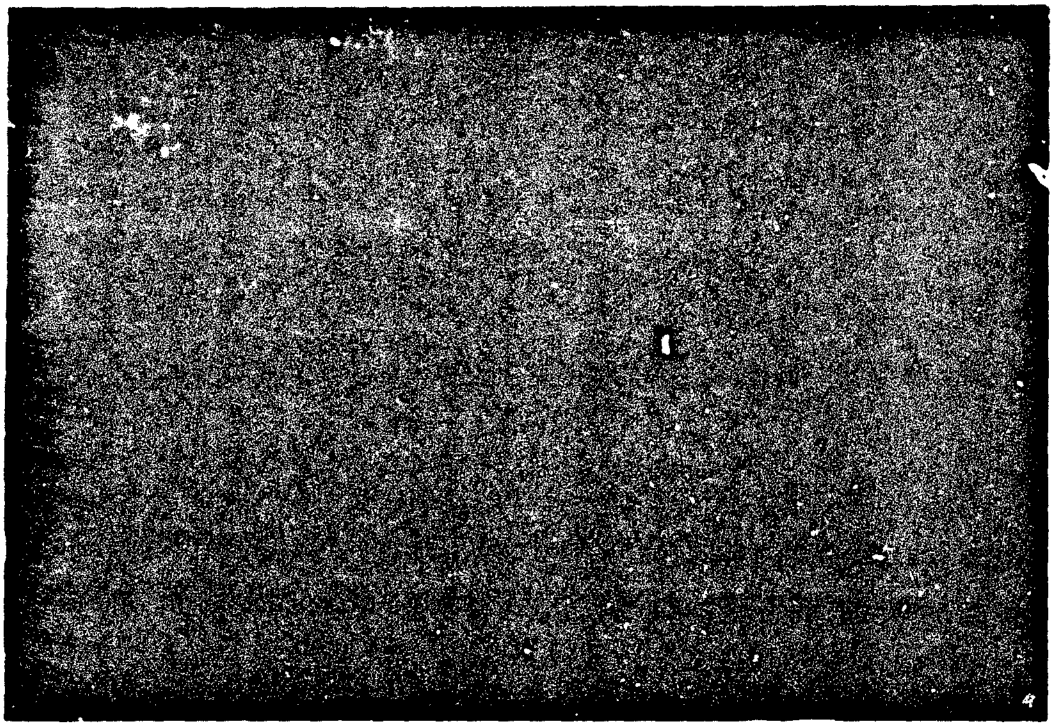


Figure 12. Preparation of Spray Mixture in 55-Gallon Drum Prior to Aircraft Loading.

D. AERIAL APPLICATION

Treatment application involved the coordinated efforts of the flight crew consisting of pilot and spray technician, the calibration grid crew, and the airport crew. Radio contact was maintained during the application period between the pilot and the calibration grid supervisor who provided meteorological data from the grid and scheduled the calibration and plot application flights. The grid supervisor was responsible for possible cancellation of test applications because of unfavorable winds or other adverse test conditions. Radio communication with the airport crew was also available to the pilot.

The typical sequence of in-flight procedures during treatment application included:

1) Initial priming of spray system and regulation to desired pressure
2) Calibration grid flight
3) Plot application
4) Calibration grid flight
5) Plot application
6) Calibration grid flight

Sprays in calibration flights and on test plots were applied at a standard airspeed of 100 knots at a height of 35 to 50 feet above the forest canopy or grid surface.

The following data were recorded by the spray technician for calculation of flow rate and spray volume delivered (Appendix D):

1) Time of spray run
2) Air speed in knots
3) Tank pressure at spray delivery
4) Duration of spray run (seconds)
5) Tank gauge reading (gallons)
6) Flight path azimuth or direction

Flow rate and gallons per acre released were calculated in flight after the first spray run to corroborate or [illegible] the pressure value settings if necessary.

On completion of spray application, data from all spray runs were composited to calculate flow rate (gpm) and spray volume delivered in accordance with the following equations:

$$\text{Flow rate in gpm} = \frac{\text{Delivered volume x 60 seconds}}{\text{Number of seconds in spray run}}$$

$$\text{Gallons per acre released} = \frac{\text{Flow rate in gpm}}{\text{23 acres per minute}}$$

The factor, 23 acres per minute, represented the area covered in a 100-ft swath in one minute at the standard 100-knot airspeed.

Immediately upon return of the aircraft from a spray application, the residue of chemical mix was drained from the tank, pump, and boom. Two 20-ml samples were taken from the drainings to be used for colorimetric standards in laboratory analysis of the grid deposit data.

The aircraft and boom system were subjected to a rigid schedule of flushing and washing after each spray flight. The aircraft was first scrubbed with water containing soap or detergent and 1% ammonia, then washed with a dilute solution of acetic acid and given a final rinse with water. Spray booms and nozzles were thoroughly flushed with water. Nozzles were checked at least once a week for deterioration of the diaphragms and gaskets.

E. LABORATORY ANALYSIS OF SPRAY DEPOSIT RATES AND VOLUMES FROM GRID CALIBRATION

Spray deposit rates and volumes for each treatment application were obtained by a colorimetric technique that is discussed in detail in Appendix C. Figure 13A illustrates the removal of the spray deposit from the exposed plate and its matching cover plate by rinsing with acetone or other appropriate solvent. Colorimetric determination of the spray material in these rinse solutions was made with a Bausch and Lomb spectrophotometer as shown in Figure 13B. Data were converted to spray deposit values expressed in gallons per acre based on standards prepared from the samples of original spray solution obtained following treatment application.

A profile of spray deposit values was graphed for each grid flight. Average deposit rates were calculated in pounds per acre of active ingredient, and maximum, mean, and minimum deposit volumes per plot. Depo. recovery values were obtained by comparing deposit volumes obtained from grid deposits with delivered volumes obtained from flight records (Appendix C). Mass median diameter of spray droplets was determined from the Kromecote cards exposed during crosswind flights.

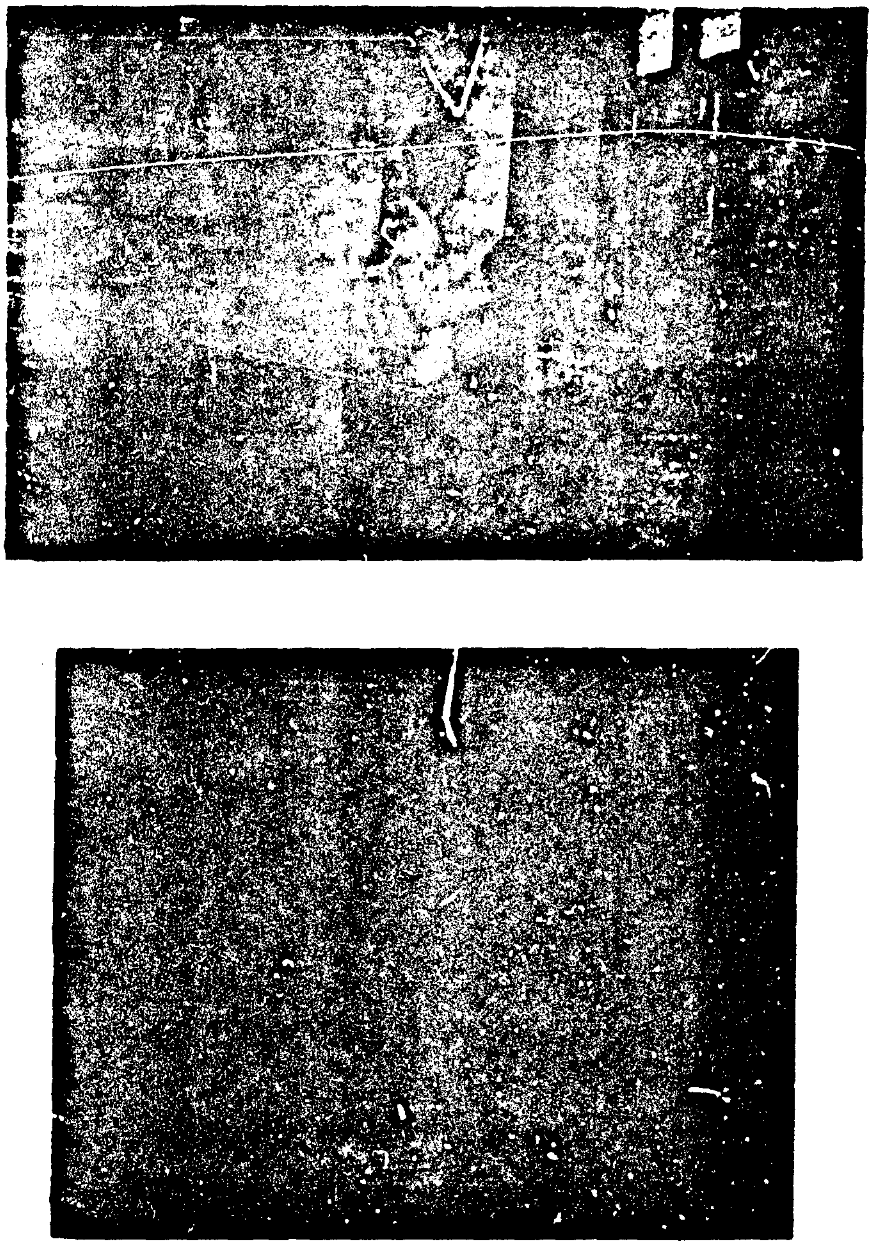


Figure 13. Laboratory Determination of Spray Deposit from Grid Calibration.
A. Spray deposit from grid plates is dissolved in acetone and made to volume in volumetric flask.
B. Light transmittance values of spray solutions are determined with a spectrophotometer.

IX. EVALUATION TECHNIQUES

A. RATIONALE

The objectives of the defoliation test program were to determine minimal effective dosage treatments with Purple and related herbicides and to evaluate the effectiveness of other chemical agents. Evaluation techniques were therefore needed that would accurately appraise the total degree of defoliation or foliage removal by a wide array of chemical treatments. The test program also provided an excellent opportunity to secure quantitative data of importance in military operations on changes in vertical and horizontal visibility in the jungle environment as affected by defoliation.

Three evaluation techniques were developed in the early stages of the project to meet these requirements: (i) visual evaluations, (ii) vertical canopy photography, and (iii) "dot-count" horizontal visibility measurements. The three types of evaluation were conducted at the following scheduled intervals to provide information on rapidity of action of chemicals and the duration and trends in defoliation responses:

1 week	2 months	6 months
2 weeks	3 months	8 to 9 months
3 weeks	4 months	12 months
4 weeks	5 months	

Visual estimates of defoliation were used to appraise the defoliation response of the total vegetational cover to chemical treatment. Ratings obtained by this technique were directed primarily toward an evaluation of effectiveness of chemical treatments as related to rates, volumes, season of application, and type of chemical.

A second technique employing vertical photography gave quantitative measurements of ground-air visibility as related to defoliation response. Repeat photographs at permanent locations in each treatment plot provided a continuing record of canopy obscuration, as determined quantitatively by a compositing light meter or obscurimeter.

From the military point of view, air-to-ground vertical visibility is probably more important than ground-to-air visibility. However, the difficulties in evaluating changes in air-ground visibility by means of aerial observations or photography with the timing, precision, and total number of observations required for an adequate volume of data were almost insurmountable. Further, this technique would have required the placement of some type of reflective markers or targets, on or near the ground, in over 250 plots, and maintenance of these targets throughout the test period. By contrast, if it can be assumed that there is a direct relationship between air-to-ground visibility and ground-to-air visibility, the latter may be measured quickly, easily, and accurately by the careful adaptation of standard photographic techniques. The method adopted required only a very small investment in equipment and skilled labor compared to the extremely large expenses involved in aircraft operations. No targets were required and laboratory evaluation of the photographs was simple, fast, and reliable.

Horizontal-visibility measurements were obtained by the third technique that dealt with the portion of the jungle or forest environment within which the foot soldier operates. The technique involved observation of a human-sized target on eight azimuths over a range of specified distances. Horizontal-visibility data furnished a measure of effectiveness of defoliation in the shrub and ground-cover layer of the forest in contrast to the upper canopy effects measured by the vertical photography technique.

Supplemental use was made of oblique aerial photographs taken in Kodachrome, Ektachrome, and Infrared Kodachrome of individual plot treatments in recording changes in defoliation response and in determining uniformity of spray coverage. Evaluation of response was based primarily on dominant canopy.

B. VISUAL ESTIMATES OF DEFOLIATION

Visual estimates of defoliation of vegetation and individual species were used as a primary rating system of effectiveness of chemical spray treatments. Ratings were made at scheduled intervals of percentage defoliation of over-all vegetation and of the component dominant, intermediate, shrub, and ground-cover layers. Concurrent ratings on a 0 to 10 scale were made on defoliation, or regrowth, or both of individually marked trees and shrubs.

In making the appraisal on a treatment plot, the observer traversed the centrally located 500 feet of evaluation trail, recording first the defoliation of individually marked plants. Over-all estimates were then made after inspection of the entire central portion of the plot. The observer mentally composited or averaged responses of the entire vegetation profile to obtain the over-all rating.

Immediately after treatment application, notes were taken of the general spray deposit pattern, relative penetration of spray to ground level, and any irregularities in spray coverage in relation to plot boundaries and the permanent camera stations.

Periodic observations furnished information on:

1) Amount and duration of foliage removal in the over-all vegetation cover and in the various structural components of the profile including dominant canopy, intermediate tree layer, shrub layer, and ground cover.

2) Characteristics of plant response classified as (i) herbicidal action—systemic and growth-regulating effects resulting in defoliation and subsequent death, (ii) desiccant or contact action—nonsystemic effects characterized by rapid death of foliage without injury or death of plants—foliage removal followed by regrowth, and (iii) defoliant action—stimulation of leaf fall or abscission without sustained injury or death of the plant—often characterized by a rapid shedding of green leaves following application of chemical defoliants.

3) Rapidity of defoliation, herbicidal action, and other plant responses.

4) Duration of maximum or effective defoliation response.

5) Characteristics of regrowth or recovery of vegetation following defoliation.

In general, the data are considered to be a fairly reliable index of treatment effectiveness. One or two observer team members conducted each evaluation.

Replacement personnel worked with experienced observers to secure uniformity over the test period. During the dry season some difficulty was encountered in distinguishing the effects of chemicals and that of natural defoliation, particularly in Test Site II.

Treatments yielding over-all defoliation in excess of 60 to 65% were considered to be effective from the military standpoint.

C. VERTICAL PHOTOGRAPHY

Briefly, the method may be described as follows. Very high contrast photographs of the forest canopy were made with the sky as a background. These photographs were taken at six marked locations in each plot, before and at 12 intervals after treatment, according to the schedule given in Section IX, A. Each series of repeat photographs was carefully taken at exactly the same marked spot, with the camera adjusted on a tripod so the lens axis was in a precisely vertical position.

The negatives obtained were high contrast silhouettes of the upper canopy, in which the white and black areas represented obscuration and visibility, respectively. The proportion of canopy obscuration in each negative was evaluated by a compositing densitometer called an obscurimeter (Figures 14 and 15), (Appendix E).

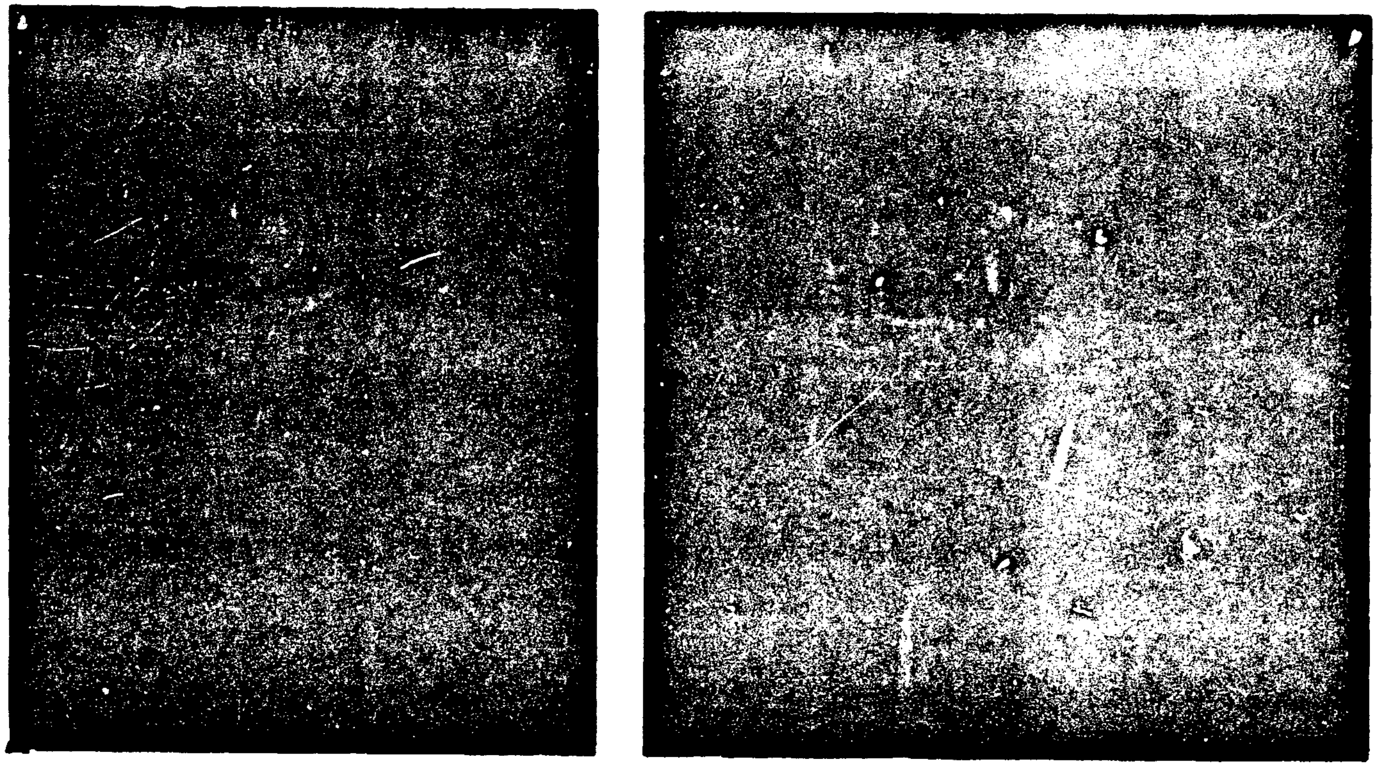


Figure 14. Vertical Photography Technique.
A. Photographer and assistant with camera vertically positioned at camera station.
B. Camera mounting showing level indicators for vertical positioning.

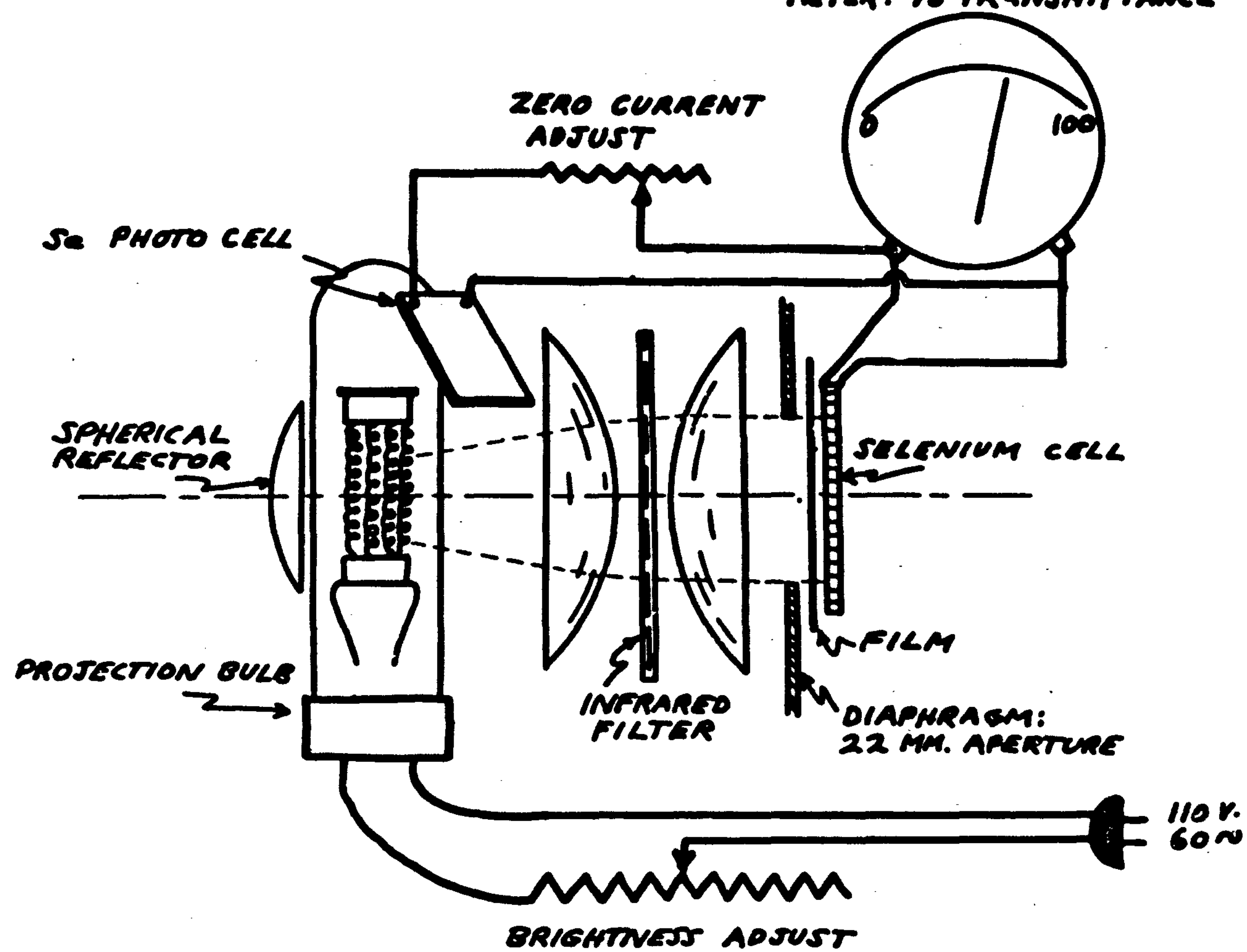


Figure 15. Diagrammatic Drawing of Obscurimeter used in Vertical Photography.

The camera used was a Nikon F, single lens reflex 35 mm, with a "waistlevel" finder. This camera was chosen because of its precision construction and rugged durability, although any camera of similar design could have been used. The 28-mm lens was chosen partly because of ready availability and as a compromise in the choice of the angle of acceptance that determines the area in the field of view (60 degrees).

The tripod has a specially made top plate to hold the camera vertical, with necessary leveling indicators. A compass was used to enable proper orientation of the camera axis consistently in the same direction throughout the series of photos.

Exposures were chosen so that the sky, as a background, was rendered dense black in the negative; the forest cover was very drastically underexposed, thus producing a black and white silhouette of the foliage and upper branch framework.

Field procedure consisted of beginning the film strip with a photograph of a sign containing the film roll number, date, and plot number. An exposure was made of open sky, with shutter speed and aperture set as determined by the exposure meter (Weston Master III) to give a normally dense sky image. The same shutter and diaphragm settings were used for duplicate negatives exposed at the six camera sites in each plot. An unexposed negative and an open-sky exposure were included for obscurimeter calibration of each roll. The period in which photographs could be taken was limited by the elevation angle of the sun from 0800 to 1100 and 1400 to 1600 hours.

Negative development was carefully standardized to secure uniform high contrast.

Films were then processed with the obscurimeter or compositing densitometer to obtain transmittance values for each negative which were then transposed to obscuration values. Instrument adjustments were made on each roll of film to give 100% transmittance by the blank frame and 0% for the fully exposed sky frame. The frames containing the canopy silhouettes were processed in succession without changing the instrument adjustment.

Obscuration values for the individual camera station in each plot were graphed to facilitate compilation of percentage and duration of response data.

D. HORIZONTAL VISIBILITY

Horizontal visibility was measured in each treatment plot at scheduled intervals by the technique developed by the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, in a research project for

ARPA.[16] The technique consisted of observations of the proportion of a human-sized target visible at specified distances from a given point. Comparisons of target visibility prior to and following treatment gave a quantitative measure of changes in horizontal visibility due to defoliation. Untreated control plots provided data on seasonal changes in visibility.

The target consisted of a set of three 10-inch discs mounted at 0.5-, 1.2-, and 1.9-meter heights on an aluminum pole (Figure 16). The white discs each had 25 randomly spaced red dots 1 cm (0.4 inch) in diameter. Visibility was determined in each treatment plot on a series of eight azimuth lines radiating from a central observation station. Camera Station 2 was used as the observation station because of its central location and accessibility.

Target visibility expressed as numbers of dots visible on each target at a given range was determined by an observer with the aid of 7 x 35 binoculars mounted on a tripod. The crew consisted of the observer, recorder, and one or two men who positioned the targets at specified distances.

In the early phase of the test program, targets were positioned at 5, 10, 15, 20, 25, and 30 meters from the observer on each of eight equally spaced azimuth lines, as suggested by Waterways Experiment Station. Visibility was determined at subsequent intervals at the same azimuth positions as determined by tape and compass. In the test sites examined in Thailand almost 100% of the target dots could be counted at five meters. Conversely, at distances of 25 meters or more, the target was seldom visible and standard errors of 100 to 300% were obtained at ranges in excess of 25 meters. For this reason, the 5-, 25-, and 30-meter ranges were dropped, and efforts concentrated on the 10-, 15-, and 20-meter ranges.

An additional modification of the horizontal-visibility technique was made following statistical tests of method error in comparisons of marked and unmarked target locations used for successive readings in the same plot. In the original system of unmarked target sites at 10, 15, and 20 meters from the center on each azimuth and azimuths located by compass and tape for each successive reading in the same plot, the confidence interval of the difference between two successive readings in the same plot was 25.5% of the total dot count at the 0.95 probability level. When target locations were permanently marked assuring that azimuths and target locations were identical for successive readings on the same plot, a confidence interval of 10.4% was obtained, indicating a much reduced variability. The technique was modified in February 1965 to incorporate marked locations of all targets for the continuing series of observations. The method using fixed target sites resulted in a significant reduction in field time required for visibility determinations.

Figure 16. Target used in Horizontal Visibility Technique.

Horizontal visibility determinations were initiated in July 1964 and were carried out by a crew of trained Thai workers under the supervision of ARPA R&DFU-T personnel or U.S. Army Biological Center personnel stationed at the field headquarters.

Data were expressed as average number of target dots visible per azimuth for each distance range. The ratio of combined target dots visible for the three ranges at any period of observation to the before-treatment reading gave an index of improvement in horizontal visibility.

E. AERIAL PHOTOGRAPHY

Oblique aerial photographs of individual treatment plots were taken from an altitude of approximately 1,000 ft with a 35-mm single-lens reflex camera on Kodachrome or Ektachrome film. These photographs were taken by project personnel from the Beechcraft plane during late morning or early afternoon hours. Photo flights were made at 1- or 2-week intervals during the period from October 1964 to March 1965.

Attempts were made to secure a weekly photographic record of the early response stages to treatments for the first month and subsequent monthly photos during the period of effective defoliation.

The photographic record of early stages of vegetation response was evaluated to provide information on spray distribution in relation to plot boundaries and uniformity of coverage. The percentage of canopy reduction or defoliation was estimated from properly exposed photographs by visual estimates and comparison with adjacent untreated vegetation. The photographs were used principally to supplement visual estimation from ground observations.

Aerial photographic coverage with panchromatic film was taken of the entire Royal Thai Army Replacement Training Center on 1 January 1964 by the U.S. Air Force photo-intelligence group at Korat, Thailand. Contact prints of four photo flights including the two test sites on a scale 1:15,000 were furnished to personnel of the OCONUS defoliation test program. These photographs provided a pretreatment record of the test sites.

Post-treatment aerial photographic coverage in panchromatic and black and white infrared film was furnished for the two sites by ARPA R&DFU-T from photo flights made under the supervision of the U.S. Army Cold Regions Research and Engineering Laboratories. Panchromatic film coverage on a scale of 1:15,000 was furnished from flights made in February 1965. Contact infrared prints, scale 1:5,000 were provided from photographs made on 15 May 1965.

Color infrared aerial photographs on 70-mm Kodak Ektachrome Aero film were taken at intervals throughout the test program. This film reproduces live and dead vegetation in sharply contrasting colors—bright red for living plants and blue for dead vegetation.

Additional post-treatment aerial photo coverage with panchromatic film has been scheduled for early 1966.

X. RESULTS

A. VISUAL ESTIMATES OF DEFOLIATION

Systematic ratings by visual estimates of defoliation were initiated in July 1964 and continued at scheduled intervals until September 1965 on all treatments showing a measurable response. Table 3 summarizes all treatments with Purple, Pink, Orange, and Dinoxol, a commercial formulation of 2,4-D and 2,4,5-T esters. Defoliation ratings of selected treatments with other herbicides, defoliants, and desiccants are shown in Tables 4 and 5. A rating of 60 to 65% was considered minimal for effective defoliation.

1. Purple, Pink, and Orange

Defoliation ratings for Purple, Pink, and Orange treatments shown in Table 3 are arranged in sequence of season of application.

a. Late Dry and Early Rainy Season (April - May 1964)

Initial tests with Purple and Pink in April and May 1964 were conducted on Test Site I only. Evaluation ratings were started three to four months after application.

Purple applied as a pure chemical at 2.4 and 3.0 gal/acre gave effective defoliation for a period of 6 months after treatment. By 8 to 9 months following treatment, regrowth and replacement vegetation consisting of rapidly growing woody vines and shrubs had become established and estimates of over-all defoliation were below the effective level of defoliation. Applications of Purple at lower rates (1.2 gal/acre of 100% chemical or 1.8 gal/acre in a 1:2 mixture with diesel fuel) produced effective defoliation for 4 or 5 months only. A treatment with 0.9 gal/acre in a 1:2 mixture with diesel fuel gave a minimal effective rating on one replicate plot only.

Pink applied as a pure chemical at 1.6 gal/acre was highly effective for a 5-month period. Minimal effective defoliation was secured at rates approximating 1 gal/acre (7.2 and 8.6 lb/acre acid equivalent in 1:2 and 1:5 mixtures of Pink and diesel fuel). Application at 6.0 gal/acre vs. 2.5 gal/acre did not significantly affect the degree of defoliation secured.

b. Late Rainy Season (August - September 1964)

Treatments with Purple and Pink were replicated on Test Sites I and II in late August and September.

TABLE 3. VISUAL ESTIMATES OF VEGETATION DEFOLIATION FROM APPLICATIONS OF PURPLE, PINK, AND ORANGE ON TEST SITES I AND II FROM APRIL 1964 TO JUNE 1965

Chemical and Treatment	Rate/Acre Gal	Rate/Acre lb	Ratio of Chemical to Oil in Mixture	Test Site	% Defoliation at Indicated Time Interval after Application: 1 mo	2 mo	3 mo	4 mo	5 mo	6 mo	8-9 mo	12 mo
					EARLY RAINY SEASON (APR-MAY 1964)							
Purple												
1	1.2	10.3	100%	I				60	60	40	10-15	40
				I				80	50	40	<10	<10
2	2.4	20.6	100%	I				85	85	45	10	25
				I				90	70	60	40	<10
9	3.0	25.8	100%	I			90	75	70	70	40	45
				I				70	60	60-65	55-60	15
3	0.9	7.6	1:2	I				65	60	40	10	30
				I				40	45	30	10	30
7	1.8	15.4	1:2	I			85	85	75	40	35-40	55-60
				I				60	50	30	40	35-40
Pink												
4	1.6	13.8	100%	I			85	85	80	40	25	20
				I				80	85	50	40	30
5	0.9	7.7	1:1	I				75	60	30	20	20
				I				70	55	50	20-25	<10
6	0.8	7.2	1:2	I				80	60	40	25	30
				I				60	20	20	25	<10
8	1.0	8.6	1:5	I			75	60	45	50	15	40
				I			85	55	40	30	10	25
					LATE RAINY SEASON (AUG-SEP 1964)							
Purple												
30	3.5	30.0	100%	I	30	50	45-50	55	45	65	30-35	10
	2.5	20.0	100%	II	50	70	65-70	70	60	55	55	35
32	0.8	7.0	100%	I	15	30	15-20	20-25	35	30	10	25
				II	20	40	60	50	45	50	10	15
26	1.1	9.5	1:1	I	35	30	40	30-35	25-30	15	10	-a/
				I	25	35	45	50	40-45	25	35	-
28	0.8	6.5	1:1	I	25	30	30-35	35-40	45	30	10	40
				I	25	30	45	35-40	25	45	10	25
Pink												
31	2.5	20.0	100%	I	40	45	50	50-55	45	70	30	10
				II	60	75	75	70	70	60	60-65	20
34	1.0	9.0	100%	I	20	35	70	45	65	45	65	-
				II	25	65	70	85	60-65	50	60	10
27	0.9	8.0	1:1	I	30	65	40	60-65	55	55	55	-
				I	30	50	55-60	45	60	65	45-50	-
29	0.6	4.5	1:1	I	20	20	35-40	30	40-45	30	40	15
				I	15	20	15-20	15-20	15-20	15	15	10
Dinoxol												
36	2.5	10.0	100%	I	20	30	30-35	35	25	20	10	-
				II	35	70	65-70	75	75	60	25	15-20
35	1.0	4.0	100%	I	20	25-30	15-20	30	20	20	10	-
				II	25	60	60	75	30	30	20	10
37	1.5	6.0	1:1	I	25	60	50	65	50	55-60	25	15
				II	35	35-40	60	50	50	40	55-60	10
					DRY SEASON (DEC 1964-FEB 1965)							
Purple												
5.	3.2	27.0	100%	I	10-15	10	25	60	40-45	40	30-35	
				II	20	75	80	75-80	65-70	65	40-45	
53	2.1	18.0	100%	I	15	10	25	60	40-45	25-30	40	
				II	20	50	70	70-75	75	65	55-60	
57	1.2	10.3	100%	I	10-15	15	-	-	-	-	-	
				II	25	45	50	40	25	45	15	
55	1.1	9.8	1:1	II	45-50	60	70	75	65-70	60	-	
				II	35	45	60-65	35-40	35-40	40	50	
60	0.7	6.0	1:1	II	15	25	40	35	15	10-15	10	
				II	25	35	60	40	35-40	25-30	20	

Chemical and Treatment	Rate/Acre Gal	Rate/Acre lb	Ratio of Chemical to Oil in Mixture	Test Site	% Defoliation at Indicated Time Interval after Application 1 mo	2 mo	3 mo	4 mo	5 mo	6 mo	8-9 mo	12 mo
					DRY SEASON (DEC 1964-FEB 1965)							
Pink												
54	2.0	17.2	100%	I		Incorrect Application						
				II	30	60	60	80	65-70	30-35	35	
58	0.6	5.2	100%	I	15	10	-	-	-	-	-	
				II	15-20	35	65-70	65	70	70	40	
56	1.3	11.2	1:1	II	30-35	60	90	90-95	85	65-70	70	
				II	30	50	70	50	45-50	40	40	
59	0.7	6.0	1:1	II	20	35	70	40	50	35-40	25-30	
				II	35	60	65	45	45	40	40	
Orange												
61	2.5	21.0	100%	I	25	85	70	75	55-60	15-20		
				II	50	Plot Partially Burned						
63	1.5	12.8	100%	I	45	60	55	40	35-40	-		
	1.0	8.6	100%	II	45	55	45	45	45-50	30-35		
62	1.2	10.0	1:1	II	50	75	45	55	40	15-20		
				II	60	75-80	40	50-55	50	40		
64	0.7	5.5	1:1	II	60-65	25-30	45	10	10	35		
				II	55-70	60	30	40	35-40	-		
69	0.7	5.4	1:1	I	25	40	25	40	30	20-25		
				II	65-70	65-70	40	45-50	55	35		
					EARLY RAINY SEASON (MAY-JUNE 1965)							
Purple												
90	2.6	22.0	100%	I	60	65	60	60				
				II	65-70	75	65-70	35				
87	1.7	14.6	100%	I	20	50	35	-				
				II	90	85-90	65	-				
86	1.1	10.0	100%	I	10	10-15	-	-				
				II	75-80	65-70	60-65	-				
88	0.9	7.8	1:1	I	75	40-45	55-60	15-20				
				II	90	80-85	45	55				
89	0.6	5.6	1:1	I	45	25	25-30	10				
				II	75	80-85	15-20	15-20				
Pink												
91	2.2	17.6	100%	I	45	40	65	55-60				
				II	80	90	80-85	75				
93	1.8	14.8	100%	I	55	50	25-30	35				
				II	25	55-60	40	45-50				
92	1.1	8.8	1:1	I	40	50	55-60	60				
				II	55	45-50	25-30	35				
94	0.7	6.2	1:1	I	45	65	45-50	30				
				II	90	85-90	65	-				
Orange												
96	1.8	15.2	100%	I	25	40	70	-				
				II	60	85	85	-				
95	1.3	11.4	100%	I	30-35	30	35	25-30				
				II	45	65-70	75-80	-				
98	1.0	8.8	1:1	I	30	40	60					
				II	40	80-85	45					
97	0.7	6.6	1:1	I	30	35-40	55-60					
				II	40	80	40					
99	1.2 Plus 0.5 lb Tordon	9.1	1:1	I	65	85-90	80					
				II	40	45-50	30-35					

a. No data. Evaluation terminated.

TABLE 4. VISUAL ESTIMATES OF DEFOLIATION BY SELECTED DEFOLIANTS AND DESICCANT TREATMENTS FOR A SIX- TO NINE-MONTH PERIOD AFTER TREATMENT

Chemical and Treatment	Date	Rate, lb/acre	Test Site	% Defoliation at Indicated Time Interval after Application									
				1 wk	2 wk	3 wk	1 mo	2 mo	3 mo	4 mo	5 mo	6 mo	9 mo
Cacodylic Acid													
13	30 May 64	7.0	I					25	10	-[a]/	-	-	-
			I					30	15	10	-	-	-
14	3 Jun 64	5.0	I					30	30	10-15	-	-	-
			I					50	40	10-15	-	-	-
42	17 Oct 64	6.0	I	30	50	60-65	65	45-50	35-40	20	25	20-25	-
			II	30	60	60	65	35-40	20	30	30	30	-
71	4 Mar 65	3.4	I	10	25	45	35	25-30	25	10-15	<10	<10	-
			II	20	60	65	70	45-50	15-20	30	20	20	-
Sodium Cacodylate													
70	1 Mar 65	1.8	I	20	25	30-35	35-40	35-40	10-15	10-15	-	-	-
			II	10	10	35	15-20	35-40	10-15	15	-	-	-
Diquat													
11	22 May 64	2.7	I						<10	<10	-	-	-
			I						<10	<10	-	-	-
15	5 Jun 64	4.0	I					35	10-15	<10	-	-	-
			I					50	10-15	10	-	-	-
43	19 Oct 64	5.0	I		50	50	45	40	30	30	50	25-30	20
			II	40	65	80	85	35	20	25	25	25-30	30
44	22 Oct 64	2.8	I	30	45-50	45	35-40	35-40	25-30	35	25	30-35	20-25
			II	45	60	60	40-45	30	20	25	25	25-30	35
72	8 Mar 65	2.2	I	15	30	20-25	35	30-35	15	20	<10	-	-
			II	15	45	30	40	35-40	10	20	10	10	-
73	10 Mar 65	3.8	I	20	25	25	30	40	10-20	10	20	-	-
			II	20	40	40	40	35	15-20	20-25	10-15	15	-
Diquat & Amitrole													
74	13 Mar 65	>4.8	I	10	20	20	20-25	25-30	20-25	25	10	10	-
	18 Mar 65	7.2	II	10	25	25	50	30	20	20	15	-	-
Endothall Salt													
20	21 Jul 64	5.0	I		10	<10	<10	-	-	-	-	-	-
			I	20	15	<10	-	-	-	-	-	-	-
21	22 Jul 64	3.5	I	Readings void because of drift									
			I		10	15	<10	-	-	-	-	-	-
48	14 Nov 64	3.3	II	<10	15-20	25	20-25	25-30	30	30	30	20	20
	16 Nov 64	3.4	II	<10	15-20	<10	15-20	<10	25	<10	-	-	-
Endothall Acid in [illegible]													
49	29 Nov 64	5.5	II	25-30	35-40	10-15	10-15	10-15	20-25	10	15	10-15	-
			II	10	20	20-25	25-30	<10	20	35	30-35	30	35-40
79	17 Mar 65	4.5	I	-	10-15	15	20	<10	<10	-	-	-	-
			II	35	40	35	45-50	45	30	45-50	35-45	10-15	-

a. No data. Evaluation terminated.

TABLE 5. VISUAL ESTIMATES OF DEFOLIATION BY SELECTED HERBICIDE TREATMENTS FOR A SIX- TO NINE-MONTH PERIOD AFTER TREATMENT

Chemical and Treatment	Date	Rate, lb/acre	Test Site	% Defoliation at Indicated Time Interval after Application						
				1 mo	2 mo	3 mo	4 mo	5 mo	6 mo	9 mo
Dicamba Amine										
22	22 Jul 64	15.0	I	50	45	40	65-70	50-55	40	30
			I	20	40	55	55	50	50	55
23	28 Jul 64	6.0	I	30	40	35	25-30	45-50	25	35
			I	50	40	40	45-50	45-50	40	30
45	24 Oct 64	6.8	I	<10	<10	-[a]	-	-	-	-
			II	45-50	35-40	40	45	50	65-70	30
Dicamba Acid										
77	26 Mar 65	10.8	I	35-40	80	80	85-90	75	-	-
			II	60-65	75-80	65	55-60	50	-	-
78	24 Mar 65	3.9	I	35	30-35	35	35	<10	-	-
			II	40	70	55-60	40-45	50	-	-
Tordon										
75	22 Mar 65	2.8	II	80-85	75	55	50	55	-	-
			II	20	45-50	50-60	50	70-75	-	-
Tordon + Diquat										
50	27 Nov 64	1.2+2.5	II	50	45	50	60	40-45	65	45-50
			II	35-40	60	65	70	70-75	50	25-30
Tordon + 2,4-D										
51	28 Nov 64	2.3+5.3	II	10	40	55	75	80	40	35-40
			II	55-60	55	55	65	90	65	25

a. No data. Evaluation terminated.

Only one of four treatments with Purple gave effective defoliation. Treatment 30 of 100% Purple applied on Test Site II at 2.5 gal/acre was effective for a 5-month period. During the application of this treatment, leakage developed in one boom prior to spraying the second replicate on Test Site I, resulting in a higher spray deposit rate estimated to be 3.5 gal/acre. Uneven distribution of spray deposit was evident from later aerial observations. Ratings on this replicate were below minimal effectiveness in spite of the higher application rate. Applications of 0.8 to 1.1 gal/acre of 100% Purple and 1:1 mixtures with diesel fuel were not effective.

Pink applied as pure chemical at 1.0 and 2.5 gal/acre gave effective defoliation from 2 to 9 months on Test Site II. Replicates at these rates on Test Site I gave effective defoliation ratings for a shorter interval. A 1:1 mixture of Pink and diesel fuel applied on Test Site I at approximately 1 gal/acre gave minimal effective defoliation for one or two observations within the evaluation period.

Supplemental tests were conducted with Dinoxol, a butoxy ethanol ester formulation containing 2 lb of 2,4-D and 2 lb of 2,4,5-T acid equivalent per gallon. Applications were made at 1 and 2.5 gal/acre of the 4 lb/gal formulation and at 1.5 gal/acre of a 1:1 mixture with diesel fuel. The higher rate of Dinoxol (10 lb/acre) produced effective defoliation on Test Site II from 2 to 6 months after treatment. A minimum level of effective defoliation was attained for brief periods following treatment at either 4.0 or 6.0 lb/acre.

c. Dry Season (December 1964 - February 1965)

Purple applied in December and early January at approximately 2 and 3 gal/acre gave effective defoliation on the secondary vegetation of Test Site II but replicate tests were ineffective on Test Site I. A 1:1 mixture of Purple and diesel fuel at 1.1 gal/acre (9.8 lb/acre acid equivalent) caused effective defoliation on one replicate containing large amounts of bamboo in Test Site II. Ratings on this and other plots dominated by bamboo are based on vegetation exclusive of bamboo. Bamboo did not defoliate readily from applications of Purple at 1 and 2 gal/acre. Over-all ratings including bamboo did not reach minimal effective defoliation.

Pink was evaluated at four rates, principally on Test Site II. Effective defoliation was obtained on this site with pure chemical at 2.0 gal/acre and 2.6 gal/acre of a 1:1 mixture with diesel fuel (equivalent to 11.2 lb/acre acid equivalent). Data for a replicate test at 2.0 gal/acre on Test Site I are not available because of incorrect application. Treatment 58 of Pink at 0.6 gal/acre was ineffective on Site I and showed minimal effective defoliation on Test Site II.

Initial tests with Orange were made in February 1965. Application of 2.5 gal/acre of pure chemical gave effective defoliation on Test Site I for a 4-month period. The replicate plot on Site II was destroyed by fire about 2 months after treatment presumably associated with effectiveness of the chemical. Orange applied as a pure chemical at the rate of 1.5 gal/acre was judged ineffective by visual estimates on both test sites. Mixtures of Orange and diesel fuel applied at rates of 5.5 and 10.0 lb/acre on Test Site II were not effective during the dry season according to visual estimate data.

d. Rainy Season (May - June 1965)

Preliminary evaluations are shown in Table 3 for the first 3 or 4 months following applications of Purple, Pink, and Orange in the early rainy season of 1965. Replicate plots of each treatment were located on Test Sites I and II.

Purple gave effective defoliation on both test sites from applications at 2.6 gal/acre and on Test Site II at rates of 1.1 and 1.7 gal/acre. When Purple was applied in 1:1 dilutions in diesel fuel at 1.3 to 1.8 gal/acre, effective defoliation occurred during the first 2 months at Test Site II only.

Pink was highly effective for 4 months when applied as a pure chemical at 2.2 gal/acre on Test Site II but only minimal ratings were obtained on Test Site I at the third month after treatment. Somewhat variable results were obtained with lower rates of Pink; effective defoliation occurred only on Test Site II from treatment 94 with 0.7 gal/acre in a 1:1 mixture.

Orange applied as a pure chemical at 1.3 and 1.8 gal/acre gave effective defoliation for 3 months on Test Site II but was ineffective on Test Site I. Dilutions with diesel fuel containing 1 gal/acre or less of chemical were effective only at 2 months on Test Site II. A combination treatment containing Orange in a 1:1 mixture at 9.1 lb/acre and 0.5 lb/acre of Tordon produced effective defoliation ratings for 3 months on Test Site I but was ineffective on Test Site II.

e. General Summary

Purple caused effective defoliation for a period of 2 to 6 or more months from applications of 2 gal/acre or more (15 lb/acre acid equivalent as shown in Figure 17) in which average and maximum rates of defoliation are plotted against application rates. Both percentage of defoliation at maximum and duration of effective defoliation increased with the rate of Purple applied. The period of effective defoliation did not exceed 6 to 8 or 9 months.

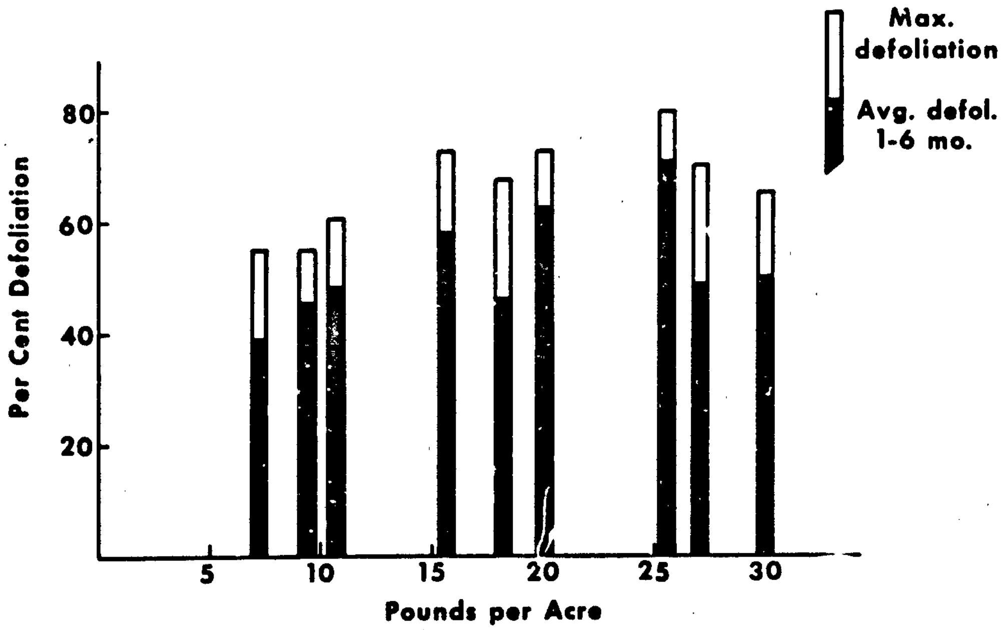


Figure 17. Trends in Maximum and Average Defoliation for Six Months Following Treatment by Purple in Relation to Dosage Rate. Data based on visual estimates.

Pink caused effective defoliation at lower rates than Purple, based on data for average defoliation for the period 1 to 6 months after application. Pink applied at 1.5 to 2.5 gal/acre gave effective defoliation for periods of 6 to 9 months.

Evaluation of Orange was conducted over a shorter test period than Purple or Pink. Available data indicate that Orange is closely comparable in effectiveness to Purple.

2. Selected Defoliants, Desiccants, and Herbicides

Treatments with several commercially available defoliants, desiccants, and herbicides were applied in three 2-month periods alternating with tests involving Purple, Pink, and Orange. Evaluation data on selected defoliants and desiccants are shown in Table 4; data on other herbicides and herbicide mixtures are shown in Table 5.

a. Defoliants and Desiccants

(1) Cacodylic Acid and Sodium Cacodylate

Cacodylic acid was initially treated at 5.0 and 7.0 lb/acre in Test Site I. Systematic evaluations are not available for the first few weeks but moderate to extreme defoliation was noted about one month after treatment. Treatments made in October 1964 and March 1965 at rates of 3.4 to 6.0 lb/acre caused effective defoliation 2 to 4 weeks after application. The sodium cacodylate treatment at 1.8 lb/acre was relatively ineffective on both test sites.

Regrowth of woody vegetation occurred 2 months following application of cacodylic acid but visible effects of treatment continued for 4 to 6 months.

(2) Diquat

Initial tests with diquat at 2.7 and 4.0 lb/acre gave moderate to extreme defoliation in the first month after application, but effectiveness diminished rapidly in 3 to 4 months because of regrowth. Applications at 2.8 and 5.0 lb/acre near the end of the rainy season (October) gave effective defoliation for a period of 2 to 4 weeks on secondary vegetation on Test Site II. Rates of 3 to 5 lb/acre are apparently required for effective treatment.

Treatments during the dry season (March) were ineffective at rates of 2 to 4 lb/acre. An additional treatment of diquat with amitrole added as an active translocating herbicide failed to give effective defoliation.

A mixture of diquat and Tordon is discussed in Section X, A, 2,b(2).

(3) Endothall

Endothall was tested in a salt formulation in water solution and in acid formulation in a dimethyl formamide-water emulsion at rates up to 5.5 lb/acre. The salt formulation gave slight defoliation for 1 to 3 months. Endothall acid produced slight to moderate defoliation from the November and March applications, but results were generally unsatisfactory.

(4) Merphos - Folex

Tributyl phosphorotrithioite, which is formulated both as Merphos, an oil-soluble concentrate, and Folex, an emulsifiable concentrate, was applied in oil and water solutions at rates of 6.0 to 28.0 lb/acre in early- and late-rainy-season applications. Evaluation data are not tabulated as the treatments were ineffective. Maximum defoliation readings of 10 to 15% were obtained at the rate of 28 lb/acre.

(5) Butyne Diol

Butyne diol was applied in three treatments at rates of 4.5, 6.0, and 11.0 lb/acre in May and November. The chemical was ineffective and resulted in only slight defoliation ratings in 3 to 4 weeks. Regrowth took place rapidly following initial desiccant action.

(6) Tributyl Phosphate

Tributyl phosphate, an active desiccant and defoliant, was tested at 10, 12, and 24.0 lb/acre during the early- and late-rainy season. The chemical was rated ineffective under the test conditions, as only slight defoliation occurred 2 to 4 weeks after treatment. Effects were noted principally in the dominant canopy.

b. Herbicides

Selective herbicides that were evaluated included dicamba (amine and acid formulations), amitrole, and Tordon applied single and in combination with diquat or 2,4-D. Only limited amounts of Tordon were available and tests were limited to single rates on replicate 5-acre plots.

(1) Dicamba

Dicamba amine was applied in water solutions at rates of 6.0 to 15.0 lb/acre dicamba acid equivalent. These rainy-season applications gave a moderate degree of defoliation. At the 15.0-lb/acre rate, defoliation approached the effective percentage during the fourth month but, in general, treatments were less effective than corresponding rates of Purple, Pink, or Orange.

Dicamba acid at 10.8 lb/acre in a 1:3 butanol-water emulsion gave effective defoliation ratings for 2 to 5 months on Test Sites I and II from applications during the dry season (March 1965). A lower rate (3.9 lb/acre) of dicamba acid was not effective.

(2) Tordon

Tordon was applied singly as a potassium salt and in mixtures with 2,4-D, diquat, or Orange.

Effective defoliation was obtained over a 2- to 6-month period with the diquat-Tordon mixture (2.5 and 1.2 lb/acre, respectively) applied during the rainy season on Test Site II. Ratings declined below the effective level at the 8- to 9-month reading.

Tordon in combination with 2,4-D amine at 2.3 and 5.3 lb/acre, respectively, gave effective defoliation 4 to 6 months after treatment during the late rainy season.

Tordon was applied alone at a single rate (2.8 lb/acre) during the dry season. Somewhat variable but generally ineffective results were obtained through the 5-month evaluation period. Increased effectiveness was noted at the last rating.

An additional combination treatment of Tordon and Orange is discussed under Section X,A,1,d.

(3) Amitrole

Amitrole applied at a rate of 6.3 lb/acre in water solution with surfactant barely gave an indication of treatment in the months following application. Slight chlorosis or yellowing of foliage in the dominant canopy and in some of the more susceptible shrub species was the main evidence of treatment.

B. MEASUREMENT OF UPPER CANOPY DEFOLIATION BY VERTICAL PHOTOGRAPHY

Photographic records of defoliation as measured by canopy obscuration were obtained for the entire series of test applications including 14 untreated control plots on each test site. Data in Tables 6 to 8 show the maximum decrease in percentage obscuration due to treatment according to the equation:

$$\frac{\text{\% obsc. prior to treatment} - \text{\% obsc. at max. effect}}{\text{\% obsc. prior to treatment}} \times 100$$

Additional data include a summary of the number of months to maximum effect, duration of the maximum effect, and the number of months to 50% recovery of the original pretreatment condition.

Seasonal trends in obscuration based on data from untreated control plots for the two test sites are shown in Figure 18. Obscuration values decreased markedly during the dry season from January to April as affected by the deciduous character of the vegetation. Test Site II showed a greater seasonal change than Site I because of the prevalence of deciduous shrubs and lack of overstory dominants.

1. Purple, Orange, Pink, and Dinoxol

Mean treatment data for the two test sites are shown in Table 6 for applications of Purple, Orange, Pink, and Dinoxol arranged by dosage rate groups, without regard to season of application.

TABLE 6. EFFECTS OF PURPLE, ORANGE, AND RELATED HERBICIDES ON UPPER CANOPY FOLIAGE AS MEASURED[a] BY CHANGE IN VERTICAL OBSCURATION

Chemical	Treatment		Rate, lb/acre a.e.[b]	Maximum % Decreased Obscuration	Months to Max. Effect	Months Duration Max. Effect	Months to 50% Recovery
			0.5 to 1.0 gal/acre (4 to 8.5 lb/acre)				
Purple	89		5.6	47.0	1.7	1.5	4.0
	60		6.0	78.0	3.0	1.5	6.0
	28		6.5	42.0	2.0	2.0	12.0
	88		7.8	45.0	2.0	1.0	4.0
	3		7.4	52.5	2.5	1.5	4.5
		Mean	6.7	52.9	2.2	1.5	6.1
Orange	69		6.0	38.5	2.0	1.0	3.0
	64		5.6	70.0	2.0	2.0	3.0
	97		6.6	61.5	2.2	2.0	-[c]
	63		8.6	24.0	2.0	1.0	3.0
		Mean	6.7	48.5	2.1	1.5	4.0
Pink	58		5.2	65.0	3.0	3.0	9.0
	29		4.5	36.8	2.0	2.0	5.0
	59		6.0	77.0	4.0	3.0	8.0
	94		6.2	77.5	2.0	1.5	-
	27		8.0	56.5	3.5	2.0	6.0
		Mean	6.0	62.6	2.9	2.3	7.0
Dinoxol	35		4.0	48.5	2.7	2.0	7.0
	37		6.0	69.0	4.0	3.5	>10.0
		Mean	5.0	58.8	3.4	2.7	8.5
			1.0 to 1.5 gal/acre (8.5 to 12.5 lb/acre)				
Purple	1		10.3	61.0	3.0	6.0	6.0
	86		10.0	47.5	1.5	1.7	3.5
	57		10.3	50.0	3.5	2.0	6.5
	55		9.8	81.5	2.7	1.5	6.5
		Mean	10.1	60.0	2.7	2.8	5.6
Orange	95		11.4	68.0	2.5	-	-
	98		8.8	64.0	2.5	-	-
	62		10.0	66.0	1.0	2.0	4.0
		Mean	10.1	66.0	2.0	2.0	4.0

Chemical	Treatment		Rate, lb/acre a.e.[b]	Maximum % Decreased Obscuration	Months to Max. Effect	Months Duration Max. Effect	Months to 50% Recovery
Pink	92		8.8	42.5	2.5	2.0	-
	56		11.2	81.5	3.2	2.5	6.5
		Mean	10.0	62.0	2.9	2.25	6.5
Dinoxol	36		10.0	65.5	3.75	3.5	12.0
1.5 to 2.0 gal/acre (12.5 to 17.5 lb/acre)							
Purple	87		14.6	52.5	1.5	1.0	4.0
	7		15.4	75.0	1.0	3.0	5.0
		Mean	15.0	63.75	1.2	2.0	4.5
Orange	96		15.2	72.0	1.7	-	-
Pink	93		14.8	62.0	2.0	1.5	>3.0
	4		13.8	61.5	3.0	2.5	5.0
	54		17.2	69.0	4.0	1.5	5.0
	91		17.6	65.5	2.5	2.0	>3.5
		Mean	15.8	64.5	2.9	1.9	>4.0
2.0 to 2.5 gal/acre (17.5 to 22.5 lb/acre)							
Purple	53		18.0	85.0	6.0	3.0	9.5
	90		22.4	63.0	3.0	1.5	>4.0
		Mean	20.2	79.0	4.5	2.25	>6.75
Orange	61		21.5	95.0	4.0	4.0	>8.0
Pink	31		20.0	84.0	1.5	4.5	12.0
3.0 gal/acre (25 to 27 lb/acre)							
Purple	30		25.0	71.5	3.0	6.0	>12.0
	9		25.8	83.0	4.0	2.0	7.0
	52		27.0	70.0	4.5	3.0	10.5
		Mean	25.9	74.8	3.8	3.7	9.8

a. Data represent means of individual treatments and rate groups.
b. Acid equivalent.
c. No data. Readings incomplete at time of publication.

TABLE 7. EFFECTS OF SELECTED DESICCANTS AND HERBICIDES ON UPPER CANOPY FOLIAGE AS MEASURED BY CHANGE IN VERTICAL OBSCURATION

Chemical	Treatment	Rate, lb/acre a.i.[a]	Maximum % Decreased Obscuration	Months: to Max. Effect	Months: Duration Max. Effect	Months: to 50% Recovery
Dicamba	78	3.9	32.0	4.0	-[b]	-
	45	6.8	28.0	4.0	-	-
	23	7.0	59.0	5.0	-	-
	77	10.8	40.5	2.5	3.5	5.0
	22	15.0	50.0	5.5	4.0	>9.5
Cacodylic Acid	70	1.8	38.5	1.5	0.75	2.0
	14	3.2	12.5	2.0	0.5	1.5
	71	3.4	44.5	1.75	1.0	3.0
	13	4.5	45.5	0.75-1.0	0.5	2.0
	42	6.0	56.5	0.75-1.0	1.0	>5.0
Diquat	72	2.2	46.0	1.0	1.0	2.25
	11	2.7	60.0	0.5	0.5	1.25
	44	2.8	38.2	1.75	1.25	-
	73	3.8	47.5	1.5	0.5	2.0
	43	5.0	54.0	2.0	1.5	-
Amitrole	41	6.3	0.0[c]	-	0.0	-
Butyne Diol	12	4.5	58.7	0.5	0.25	1.25
	46	11.0	33.0	1.25	0.25	1.0
Tributyl Phosphate	16	9.9	8.0	0.5	0.25	0.5
	39	24.0	7.7	0.25	0.5	1.0
Endothall	19	1.0	0.0	-	0.0	-
	18	3.3	6.4	0.25	0.5	0.75
	21	3.5	0.0	-	0.0	-
	20	5.0	6.7	-	0.0	-
	48	5.3	50.0	1.25	0.75	-
	49	5.5	52.5	1.5	0.75	-
Merphos	25	6.0	9.6	0.5	0.25	-
	24	12.0	0.0	-	0.0	-
	38	22.0	49.8	0.75	0.25	-
	40	28.0	68.0	0.25	0.25	1.0
Folex	47	13.0	5.0	-	0.0	-

a. Active ingredient.
b. No data. Evaluation terminated.
c. No effect.

TABLE 8. EFFECT OF TORDON AND MIXES CONTAINING TORDON ON UPPER CANOPY FOLIAGE AS MEASURED BY CHANGE IN VERTICAL OBSCURATION

Chemical	Treat-ment	Rate, lb/acre a.e.	Maximum % Decreased Obscuration	Months: to Max. Effect	Months: Duration Max. Effect	Months: to 50% Recovery
Tordon	75	2.8	54.5	2.0	3.0	5.0[a]
Tordon + 2,4-D	51	2.3+5.3	78.0	5.5	>2.0	>9.0
Tordon + Orange	99	0.5+9.1	74.2	1.25	>1.0	-[b]
Tordon + Diquat	50	1.2+2.5	79.0	4.0	3.5	>6.0

a. Greater than last observation.
b. No data. Did not recover to 50%.

Defoliation response from Purple treatments expressed as maximum decrease in obscuration increased with dosage rate from a value of 53% for applications of 6.7 lb/acre to 75% for treatments at 25.9 lb/acre (3 gal/acre of total esters).

Maximum decrease in obscuration from Purple occurred generally 2 to 4 months after treatment and maximum effect persisted from 1.5 to 3.7 months as indicated by group mean data (Table 6). Treatment effects as measured by the period to 50% recovery lasted from 4.5 to 10 months at the highest rate of application.

Figure 19 shows the trend in maximum percentage of decrease in obscuration as related to the rate of application of Purple. Duration of defoliation as the period of maximum effect, and number of months required for 50% recovery of the maximum effect increases at higher dosage rates (Figure 20).

Orange showed defoliation responses similar to those of Purple. Values for maximum decrease in obscuration were slightly higher at dosage rates of 15 and 20 lb/acre.

Pink treatments gave closely similar data to those of Purple in degree and duration of defoliation at comparable rates. Dinoxol applied at minimal dosage rates was slightly more effective than Purple or Orange; at 6.0 lb/acre Dinoxol gave 69% defoliation response compared with responses of 50 to 60% from Purple or Orange.

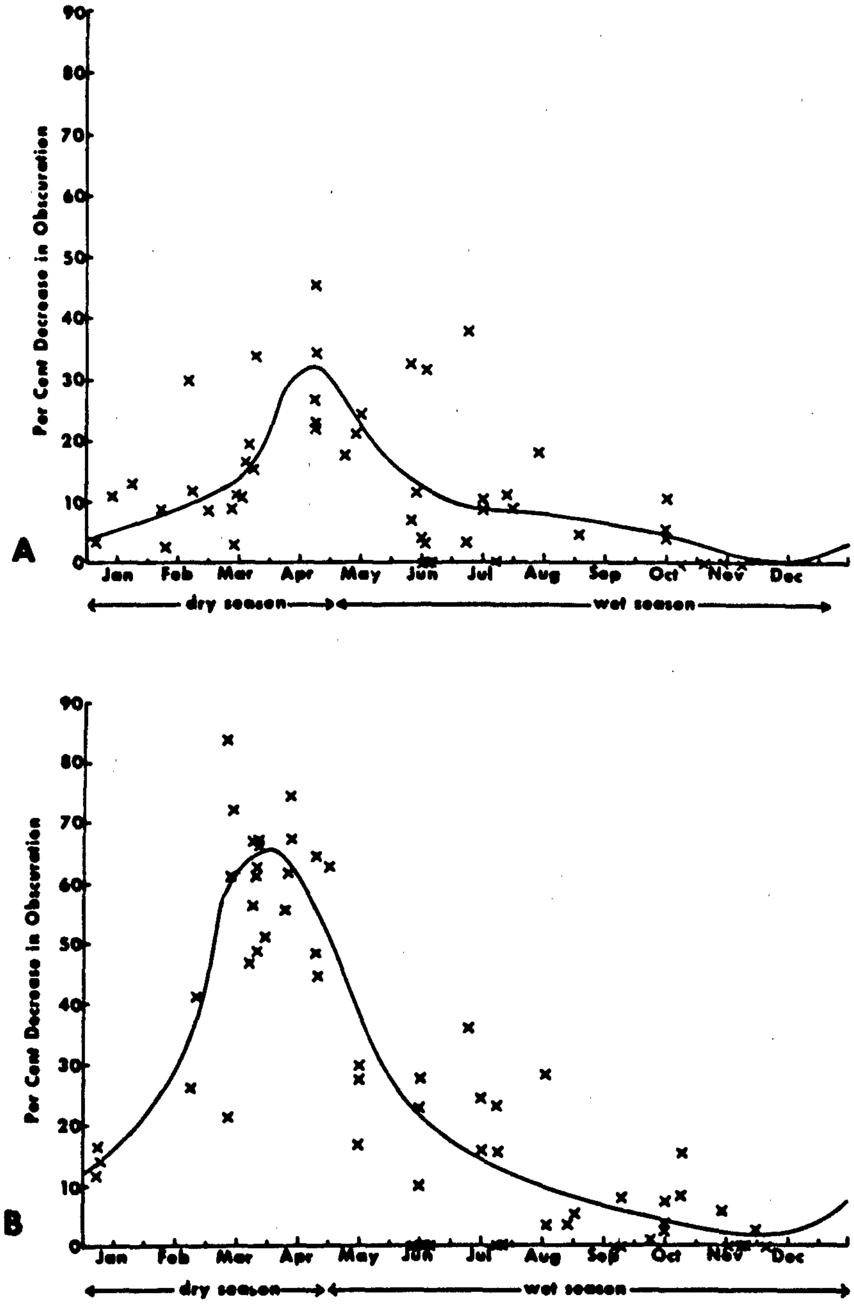


Figure 18. Seasonal Changes in Canopy Obscuration on Untreated Control Plots. Data represent individual plot values of per cent of maximum obscuration.
A. Test Site I.
B. Test Site II.

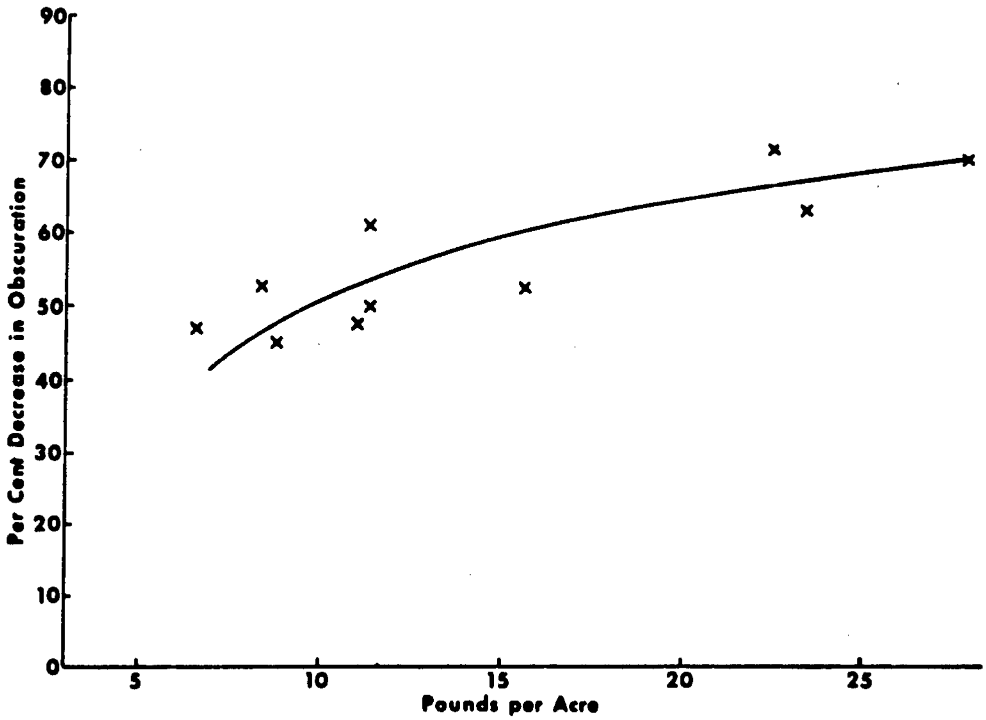


Figure 19. Relation of Maximum Per Cent Decrease in Canopy Obscuration to Dosage Rate of Purple. Data represent means from Test Sites I and II.

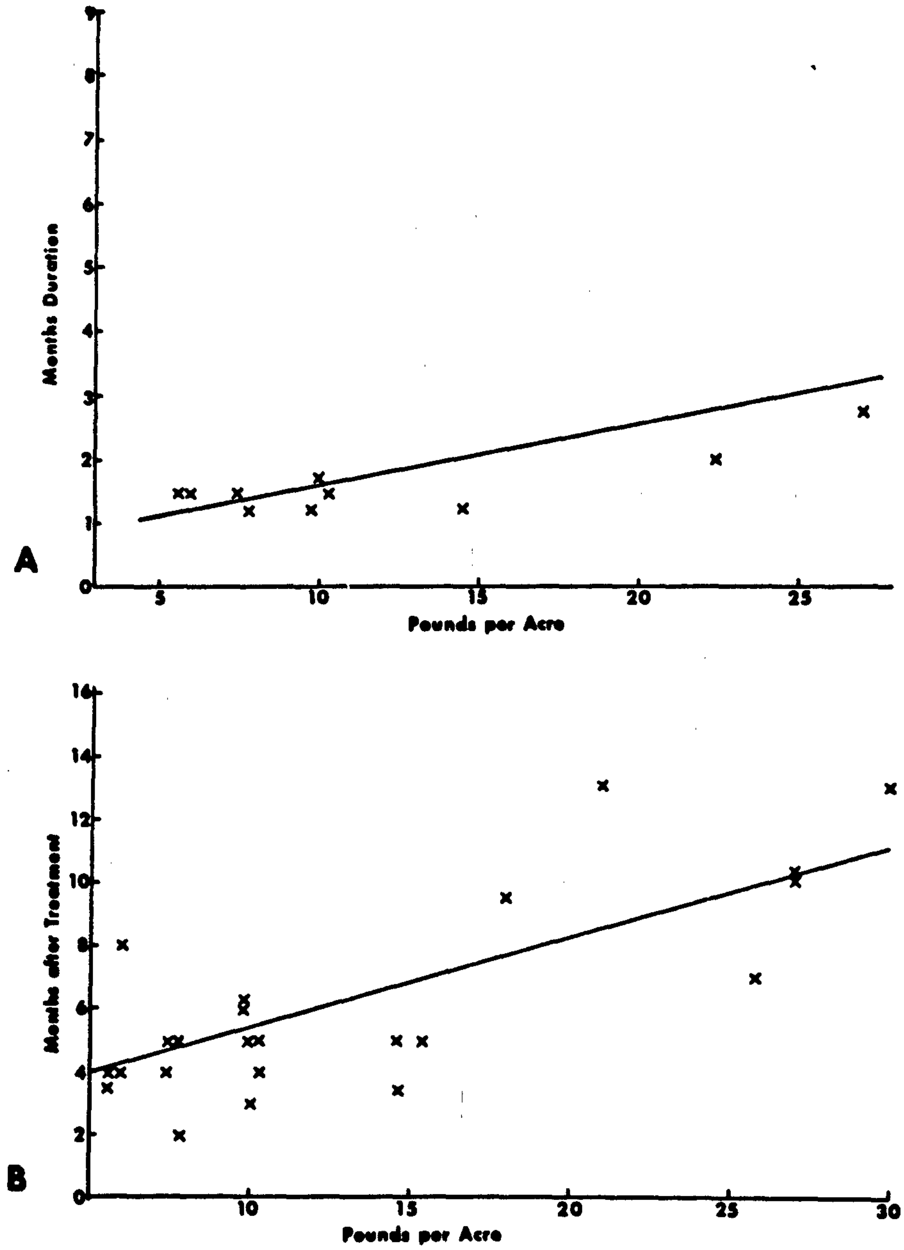


Figure 20. Duration of Defoliation Response from Application of Purple as Related to Dosage Rate.
A. Duration of maximum per cent decrease in obscuration. Data represent mean treatment values.
B. Number of months until 50% recovery from maximum response. Data represent individual plot values.

2. Selected Defoliants, Desiccants, and Other Herbicides

Data for most of the other chemicals tested are shown in Tables 7 and 8.

Dicamba gave defoliation responses of 28 to 59% for treatments ranging from 3.9 to 15.0 lb/acre. Maximum values for decrease in obscuration for dicamba were considerably lower than those of Purple, Orange, or Pink; also for cacodylic acid and diquat (Figure 21).

Cacodylic acid and diquat as desiccants gave a rapid defoliation response (2 to 6 weeks for maximum effect). Diquat gave slightly greater defoliation response than cacodylic acid at equivalent dosage rates (Figure 21). Both chemicals gave approximately 50% reduction in obscuration at a rate of 5 lb/acre.

Of the other chemicals tested only Merphos, butyne diol, and Endothall showed appreciable defoliation response. Merphos and Endothall caused minimal defoliation at their highest dosage rates. Variable results were obtained with butyne diol.

Obscuration data (Table 8) for Tordon and mixtures of Tordon with 2,4-D, Orange, and diquat show maximum responses similar to those obtained at the higher rates of Purple and Orange. Two of the four treatments required 4 to 5.5 months to attain maximum response. Approximately 80% decrease in obscuration was obtained with treatments of Tordon + 2,4-D and Tordon + diquat during the late rainy season.

C. HORIZONTAL VISIBILITY

The effects of defoliation treatments on horizontal visibility were measured on the basis of percentage of a target visible at distances of 10, 15, and 20 meters. Comparisons between initial and maximum percentage of target visibility provide an index of defoliation effectiveness of various treatments at or near the ground level.

Interception of spray by upper canopy vegetation influenced the defoliation response in the shrub and ground cover in which horizontal visibility measurements were taken. The ratio of maximum to initial horizontal visibility was consistently greater on Test Site II than on Test Site I. On Site II only a remnant of the dominant canopy remained and sprays were able to penetrate the single layer of large shrubs or small trees forming the main vegetation cover.

Initial and maximum horizontal visibility data are shown in Table 9 for applications of Purple, Orange, Pink, and Dinoxol made from August 1964 to June 1965. Similar data on selected desiccants and herbicides are shown in Table 10. Mean values are given for target visibility

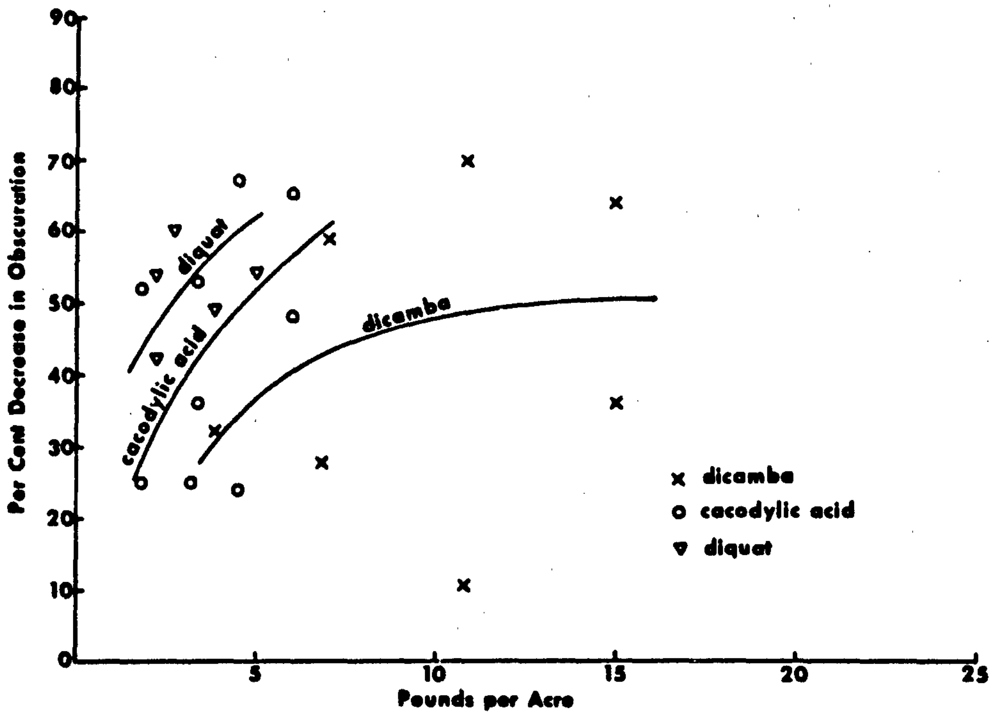


Figure 21. Defoliation Response of Dicamba, Cacodylic Acid, and Diquat in Relation to Rate of Application. Data represent plot values of maximum per cent decrease in obscuration.

TABLE 9. INITIAL AND MAXIMUM HORIZONTAL VISIBILITY RESULTING FROM APPLICATIONS OF PURPLE, ORANGE, PINK, AND DINOXOL

Chemical and Treatment	Rate, lb/acre	Mean Per Cent[a] Target Visibility Initial	Maximum	Ratio Maximum/Initial Visibility	Months to Maximum Visibility
Purple					
89	5.6	27	48	1.7-2.4	2-3
60	6.0	14	43	2.5-3.4	4-5
28	6.5	30	37	1.2-1.3	2-4
32	7.0	26	35	1.2-1.2	2-3
88	7.8	36	42	1.2-1.2	2
26	9.5	29	52	1.7	2
55	9.8	21	41	2.3-2.5	5-6
86	10.0	25	40	1.3-1.9	3
57	10.3	20	41	1.3-4.9	2-3
87	14.6	21	37	1.8-2.5	3-4
53	18.0	23	61	2.3-2.8	3-5
30	20.0	27	47	1.9	2
90	22.0	29	45	1.3-2.2	1-2
52	27.0	22	48	1.7-2.9	2-4
30	30.0	40	65	1.6	3
Orange					
64	5.5	18	36	1.8-2.1	3-4
97	6.6	25	41	1.5-1.7	3
85	8.2	25	46	1.8	2
63	8.6	27	40	1.5	1
98	8.8	13	36	2.6-2.7	1-2
62	10.0	11	30	3.0-4.0	1-3
95	11.4	19	49	2.3-3.0	1-2
63	12.8	27	49	1.8	3
96	15.2	34	48	1.2-1.7	1-2
61	21.0	19	43	2.0-2.5	2-3
Pink					
81	4.0	18	35	1.9-2.1	2
29	4.5	37	52	1.3-1.5	2-3
58	5.2	20	45	2.1-2.1	2
59	6.0	13	33	2.9-4.4	2-4
94	6.2	28	55	1.9-2.0	1
27	8.0	25	51	1.7	3
92	8.8	20	38	1.6-3.0	1-2
34	9.0	19	42	1.7-3.2	1-4
56	11.2	21	48	1.6-2.5	2-3
93	14.8	35	63	1.8-1.9	1
54	17.2	13	43	3.3	3
91	17.6	30	48	1.6-1.6	1-3
31	20.5	21	58	1.9-3.7	2-3
Dinoxol					
35	4.0	27	43	1.2-2.5	3
37	6.0	21	32	1.4-1.8	1-3
36	10.0	27	54	1.6-2.8	1-2

a. Data based on percentage of target visible at distances of 10, 15, and 20 meters.

before treatment and at the period of maximum visibility. Replicate plot data are included on the ratio of maximum to initial visibility and on the monthly intervals at which maximum improvement in visibility occurred.

TABLE 10. INITIAL AND MAXIMUM HORIZONTAL VISIBILITY RESULTING FROM APPLICATIONS OF SELECTED DESICCANTS AND HERBICIDES

Chemical and Treatment	Rate, lb/acre	Mean Per Cent[a] Target Visibility Initial	Maximum	Ratio Maximum/Initial Visibility	Months to Maximum Visibility
Cacodylic Acid					
70	1.8	32	60	1.5-3.0	2
71	3.4	21	60	2.5-3.4	2-4
42	6.0	29	55	1.3-3.6	0.7-1
Diquat					
72	2.2	30	55	1.7-2.0	2
44	2.8	22	41	1.5-2.8	0.5-0.7
73	3.8	36	55	1.5-1.6	1-2
43	5.0	18	42	2.2-2.7	0.5-3
Dicamba					
78	3.9	17	29	1.2-1.8	2-3
45	6.8	22	32	2.2	5
23	7.0	31	45	1.3-1.5	2-3
77	10.8	20	43	2.1-2.2	2-3
22	15.0	47	63	1.4-1.8	4
Tordon					
75	2.8	36	45	1.2-1.4	3
Tordon + Diquat					
50	1.2+2.5	28	54	1.7-2.5	5-6
Tordon + 2,4-D					
51	2.3+5.3	10	58	5.1-7.9	6
Tordon + Orange					
99	0.5+9.1	40	48	1.0-1.6	2-3

a. Data based on percentage of target visible at distances of 10, 15, and 20 meters.

The series of Purple treatments averaging 13.6 lb/acre acid equivalent (Table 9) resulted in a mean maximum visibility of 45% (range 35 to 65%) as compared with a mean initial visibility of 26% (range 14 to 40%). Slightly higher visibilities were obtained with increase in rate (Figure 22). Maximum increase in visibility occurred at approximately 3 months.

As measured by the horizontal visibility technique, applications of Orange at 5.5 to 21.0 lb/acre resulted in a maximum mean visibility increase of 42% (range 30 to 49%) as compared with an initial mean visibility of 22% (range 11 to 34%) (Table 9). Canopy effects from Orange applications made during the dry season and in the early rainy period showed little difference in horizontal visibility with rate of chemical applied.

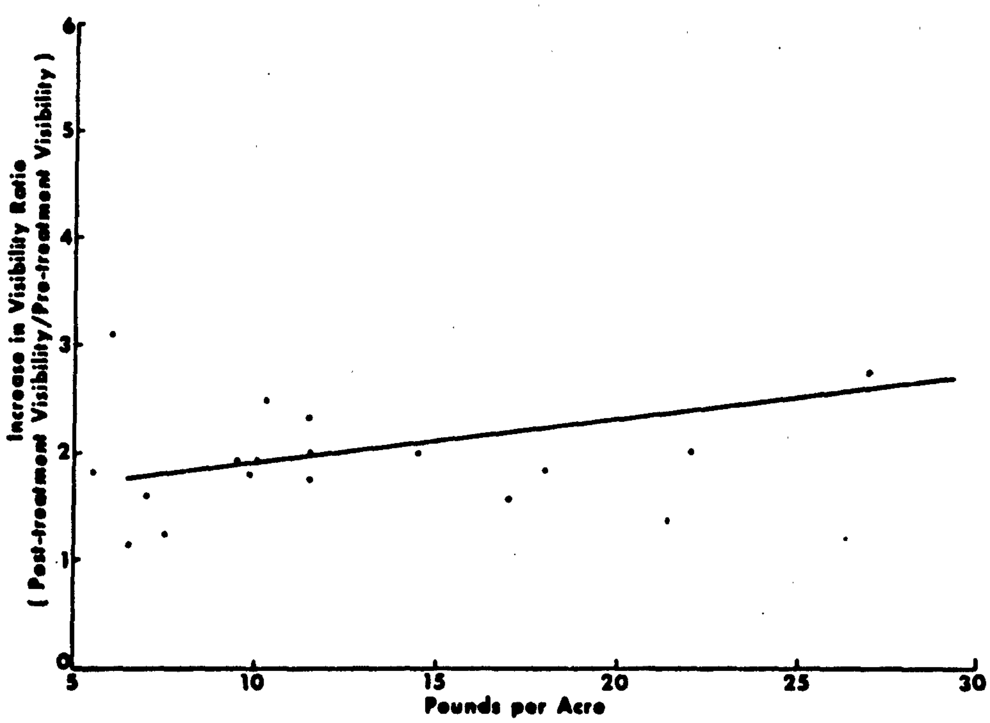


Figure 22. Relation of Maximum Increase in Horizontal Visibility to Dosage Rate of Purple Applied. Data represent treatment means of the ratio of post- to pre-treatment visibility.

Applications of Pink gave mean values for initial and maximum visibility similar to those of Purple and Orange. Maximum visibility was obtained 2 months after application. No significant trends were noted with increased rates. Dinoxol gave comparable increases in visibility to the other herbicides.

Data for cacodylic acid and diquat (Table 10) show increases in horizontal visibility equivalent to or greater than those of Purple and Orange. Cacodylic acid produced maximum visibility in 3 to 4 weeks after treatment at 6.0 lb/acre. Maximum visibility of 55 to 60% from cacodylic acid was equivalent to that obtained with 15 to 25 lb/acre (2 to 3 gal/acre) of Purple. Diquat gave slightly less improvement in horizontal visibility than cacodylic acid. Treatment 44 at 2.8 lb/acre gave maximum visibility in 2 to 3 weeks.

Dicamba applied as acid or amine at rates of 3.9 to 15.0 lb/acre was less effective than Purple or Orange. One replicate applied at 15.0 lb/acre gave a maximum visibility of 63% but net improvement over the initial reading was only 16%.

Tordon applied singly or in combination with other chemicals caused variable increases in horizontal visibility. Late rainy-season treatments of Tordon in mixture with diquat or 2,4-D were more effective than a dry-season application of Tordon alone. Treatment 51, consisting of Tordon and 2,4-D, gave the highest percentage increase in horizontal visibility of the entire test program but initial visibility was also the minimum of all treatments. In general, Tordon treatments attained maximum visibility 3 to 6 months after application.

D. AERIAL PHOTOGRAPHS

Aerial panchromatic photographs of portions of Test Sites I and II are shown in Figures 23 and 24, respectively. In Test Site I effective treatments are clearly evident in the unbroken forest canopy. A sugarcane plantation adjoins the eastern border of this site. Scattered large deciduous trees of the dominant canopy are visible throughout the area.

Figure 24 shows the calibration grid of Test Site II in the upper left portion. Secondary forest and shrub aspect of the vegetation are evident as well as previously cultivated clearings.

Figures 25 and 26 show portions of Test Sites I and II photographed with infrared film. Treatment plots with dead or dying vegetation photograph black in contrast to the lighter shades of untreated vegetation.

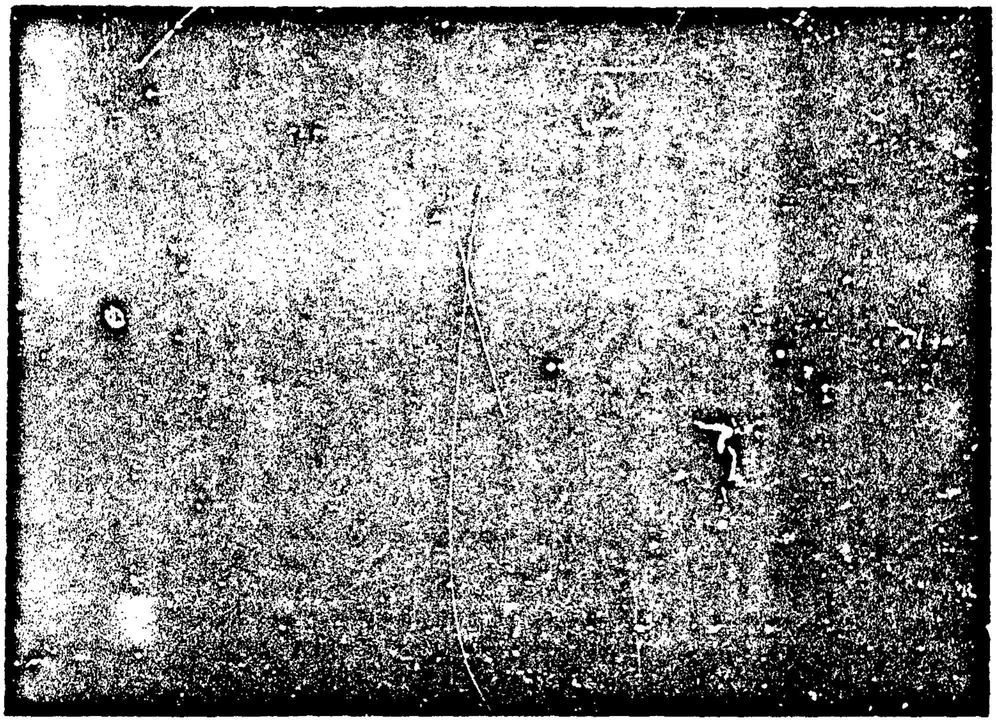


Figure 23. Portion of Test Site I Showing Treated Plots between Lane 3 (at the Bottom) and Lane 8 (Near the Top). Panchromatic film, scale 1:15,000. February 1965.

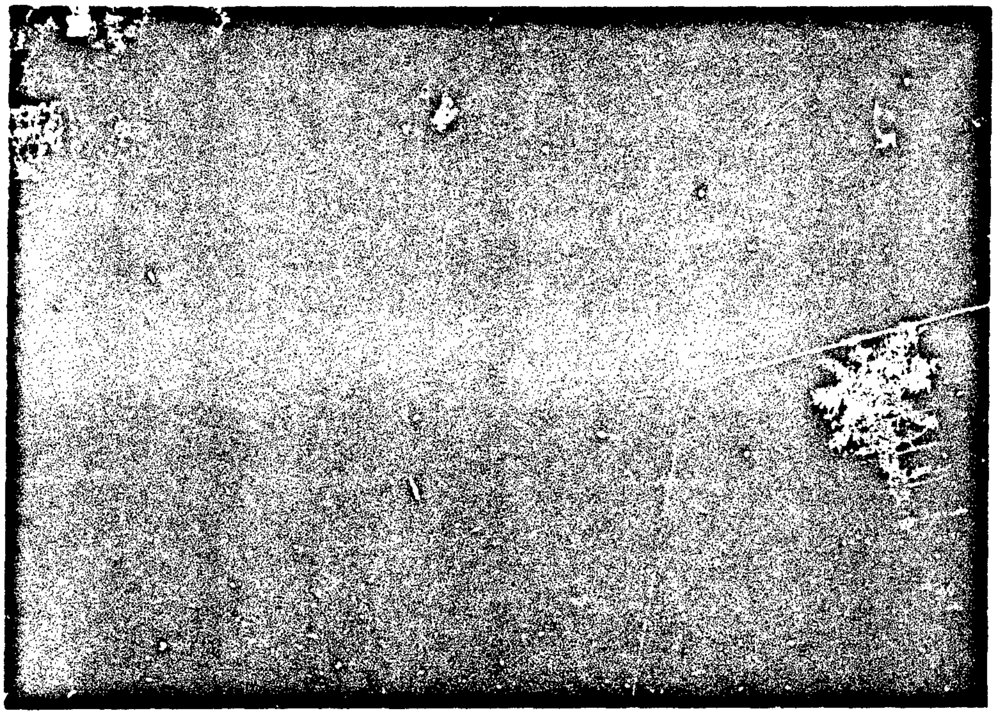


Figure 24. Portion of Test Site II Showing Treated Plots on Lanes G, H, and N in Upper Left. Calibration grid in lower left. Lane Q is roughly parallel to the road in lower right. Panchromatic film, scale 1:15,000. February 1965.

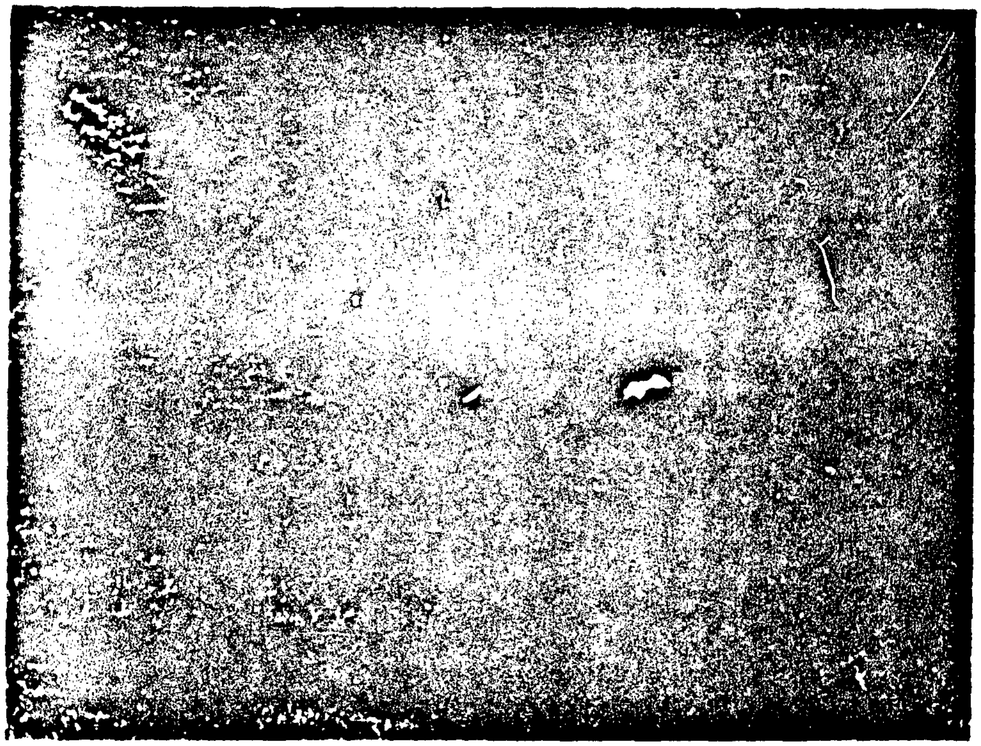


Figure 25. Detail of Portion of Test Site I Showing Dense Forest Canopy and Plot Treatments between Upper Lanes 1 and 3. Infrared film, scale 1:5,000. Treated plots photograph black. May 1965.

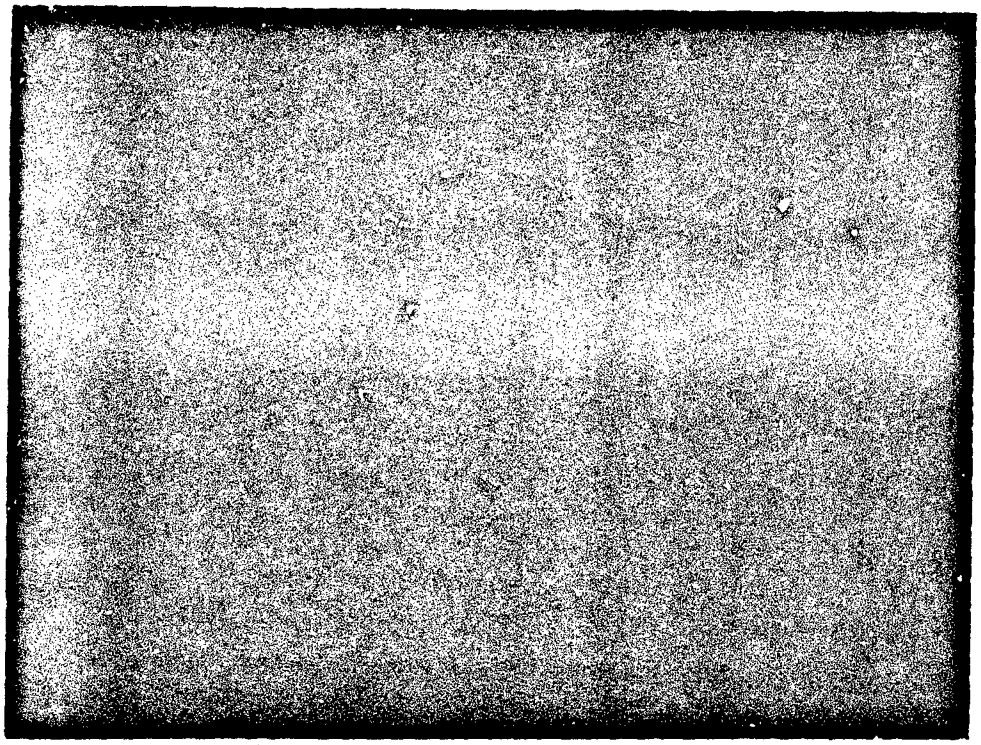


Figure 26. Detail of Test Site II Showing Partially Cleared Shrubby Vegetation and Treatment Plots between Lanes Q, P, and O. Treated areas photograph black on infrared film, scale 1:5,000. May 1965.

E. EVALUATION OF CHEMICALS

Evaluations of chemicals are presented in outline form with tentative recommendations based on the conditions of the test program.

1. Purple

a. Chemical Name

50% n-butyl ester of 2,4-D; 30% n-butyl ester of 2,4,5-T, and 20% iso-butyl ester of 2,4,5-T

b. Test Record

Number of treatments: 20
Rates: 5.6 to 30.0 lb/acre acid equivalent (0.65 to 3.5 gal/acre total ester)
Volumes: 0.65 to 5.4 gal/acre
Seasons: early rainy, late rainy, dry, early rainy

c. Type of Chemical

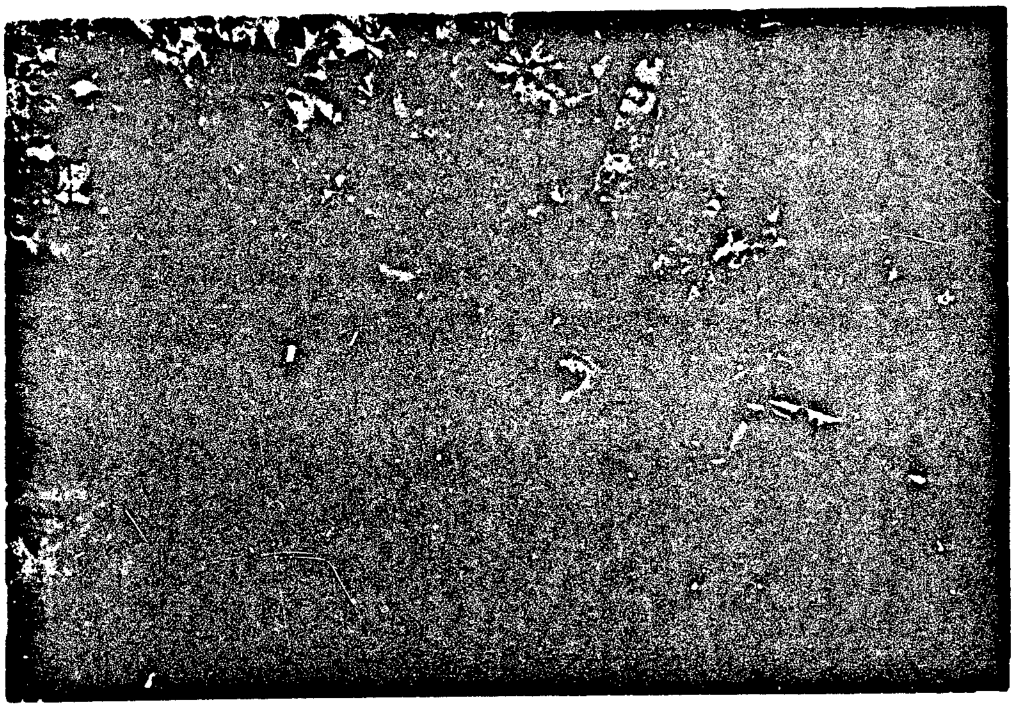
Herbicide, causing defoliation in 1 or 2 months and partial or complete top kill

d. Treatment Effects

(1) Rate

The degree of defoliation as expressed by percentage maximum response and the duration of an effective level of defoliation increased with the rate of Purple applied (Table 11). An effective level of defoliation, 60 to 65% or more as judged by visual estimates and vertical obscuration technique, was obtained with applications of Purple at 1.5 gal/acre (10 lb/acre) or more. The effective level of defoliation was reached at all rates within 2 months of the date of applications made during the growing season. Applications of 15 lb/acre or 2 gal/acre of total esters gave an average maximum effect of 70%, and effective duration lasted for 2.2 months or until 4 to 6 months after the chemical was applied. Applications of 25 lb/acre or 3 gal/acre of total ester caused an average maximum defoliation of 75% as measured by both visual estimates and vertical photography. The period of effective defoliation at this rate lasted for 3.4 months beyond the 2-month interval at which the defoliation level became effective (Figure 27).

For effective increase in air-to-ground visibility and some improvement in lateral visibility at eye level in the range of vegetation conditions represented by the two test sites, a minimum effective rate of 15 lb/acre acid equivalent or 2.0 gal/acre of total ester is recommended.



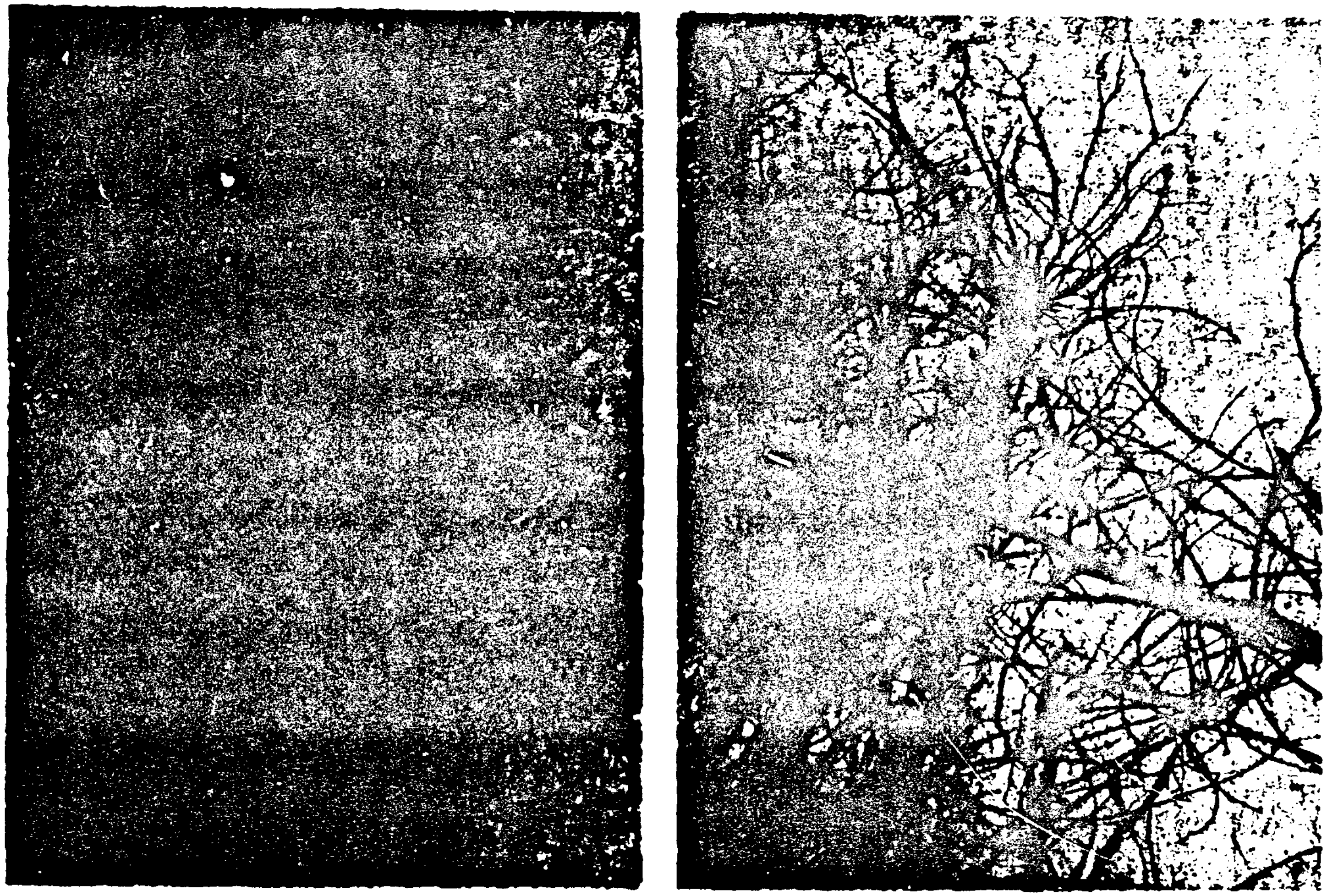


Figure 27. Defoliation Response from Purple Applied at 27 lb/acre (3.0 gal/acre) at Test Site II.
A. Pretreatment, December 1964.
B. Three months after treatment.
C. Six months after treatment.
D. Nine months after treatment.

TABLE 11. DEFOLIATION RESPONSE WITH PURPLE
USING THREE EVALUATION TECHNIQUES

Defoliation Response	Mean Rate, lb/acre			
	10	15	20	25
% Maximum Effect				
Visual Estimate	54	70	73	75
Vertical Obscuration	60	64	79	75
Horizontal Visibility	42	49	51	53
Months to Maximum Effect				
Visual Estimate	3.1	2.7	3.3	3.8
Vertical Obscuration	2.7	1.2	4.5	3.8
Horizontal Visibility	3.1	3.7	2.5	3.0
Duration of Effective Defoliation, months				
Visual Estimate	1.3	2.2	3.2	3.4

(2) Volume

Effectiveness of Purple treatments was influenced more by rate than by volume. Applications of 1 to 1.5 gal/acre of Purple as pure chemical or diluted with equal volumes of diesel fuel produced similar defoliation response.

Satisfactory spray coverage and penetration of jungle vegetation was obtained with applications of 1.5 to 2.0 gal/acre with a droplet size of 275 to 350 microns MMD.

(3) Season

Applications of Purple were less effective in the dry season than in the rainy or growing season. Purple is a systemic growth-regulating herbicide and the principal responses of the plant to the chemical are made during active growth. The herbicidal and defoliation response may be delayed until active growth starts, as for treatments made in April at the end of the dry season. Treatments 1 thru 7 (Table 3 p. 56) were applied during April 1964 and defoliation response was delayed until after the rainy season began in May.

Effective defoliation values were obtained during the dry season at the higher rates of application, especially on Test Site II. The pronounced natural defoliation occurring from February to April on this site (Figure 18B) obviously contributed to the total defoliation estimates. The true effectiveness of chemical treatments applied during this period is therefore difficult to establish.

(4) Site

Defoliation response was greater in the secondary forest and shrub vegetation of Test Site II than in undisturbed forest of Test Site I, as measured by all evaluation techniques. This difference is due, in part, to better opportunity for spray penetration in the secondary vegetation and to the substantial numbers of species that responded readily to treatment with Purple.

e. Remarks

The deciduous trees of the dominant layer or upper canopy showed a greater defoliation and herbicidal response than evergreen trees and shrubs. Some species of the intermediate tree and shrub layer showed regrowth initiating 4 to 6 months after treatment.

f. Recommendations

A minimum rate of 15 lb/acre acid equivalent or 2.0 gal/acre of Purple is recommended for effective defoliation in vegetation types represented in the test location. Applications should be limited to the rainy or growing season.

Application rate of 10 lb/acre or approximately 1.5 gal/acre may be used in secondary forest or shrub vegetation of low stature and density.

A minimum application volume of 1.5 gal/acre is desirable.

2. Orange

a. Chemical Name

50% n-butyl ester of 2,4-D and 50% n-butyl ester of 2,4,5-T

b. Test Record

Number of treatments: 10
Rates: 5.4 to 21.0 lb/acre acid equivalent
0.7 to 2.5 gal/acre of total esters
Volumes: 1.0 to 2.5 gal/acre
Seasons: dry, early rainy

c. Type of Chemical

Herbicide, similar to Purple in defoliation and herbicidal responses

d. Treatment Effects

(1) Rate

Increase in defoliation response with increase in rate similar to Purple. As measured by vertical obscuration values, maximum defoliation response increased from 55% with applications of 6.7 lb/acre to 95% at 21.0 lb/acre (Figure 28).

Effective defoliation occurred on both test sites with applications of 10 to 12 lb/acre.

(2) Volume

Volume requirements are similar to Purple. Addition of diesel fuel to chemical mixtures did not increase effectiveness.

(3) Season

Early rainy-season treatments gave effective defoliation, particularly on Test Site II.

Dry-season treatments at 2.5 gal/acre (21.0 lb/acre) gave effective defoliation on Test Site I but lower rates were ineffective.

(4) Site

Differences in response on Test Sites I and II were similar to Purple.

e. Remarks

On the basis of short-term evaluations of dry-season and early-growing-season treatments, Orange was equal in effectiveness to Purple. Orange appeared to produce a more rapid defoliation response than Purple; maximum horizontal visibility was attained 1 to 2 months after treatment with Orange as compared with that of 2 to 4 months for Purple.

f. Recommendations

Orange is equivalent to Purple in defoliation effectiveness on the basis of short-term evaluations.

The same rate that was recommended for Purple (15 lb/acre or 2.0 gal/acre) can be used for Orange.

3. Pink

a. Chemical Name

60% n-butyl ester and 40% iso-butyl ester of 2,4,5-T

b. Test Record

Number of treatments: 17
Rates: 4.0 to 20.0 lb/acre acid equivalent
0.5 to 2.5 gal/acre of total ester
Volumes: 0.5 to 6.0 gal/acre
Seasons: early rainy, late rainy, dry, early rainy

c. Type of Chemical

Herbicide, similar in defoliation response to Purple

d. Treatment Effects

(1) Rate

Applications of Pink gave effective defoliation at a lower rate than Purple. Duration of effective defoliation was greater than that obtained with Purple or Orange, extending for an 8- or 9-month period at rates of 2.0 gal/acre or more.

Applications at the rate of 8 to 10 lb/acre (1 gal/acre of total ester) appeared to be a minimal effective dosage level.

(2) Volume

Dilution of Pink with diesel fuel at ratios of one part chemical to one, two, or five parts diesel fuel did not significantly increase effectiveness.

Minimum total volume of 1.5 gal/acre is needed for adequate spray coverage.

(3) Season

Response was similar to Purple.

Apparently, effective defoliation was obtained on Test Site II at rates of 11 to 17 lb/acre during the dry season.

(4) Site

Response was similar to Purple.

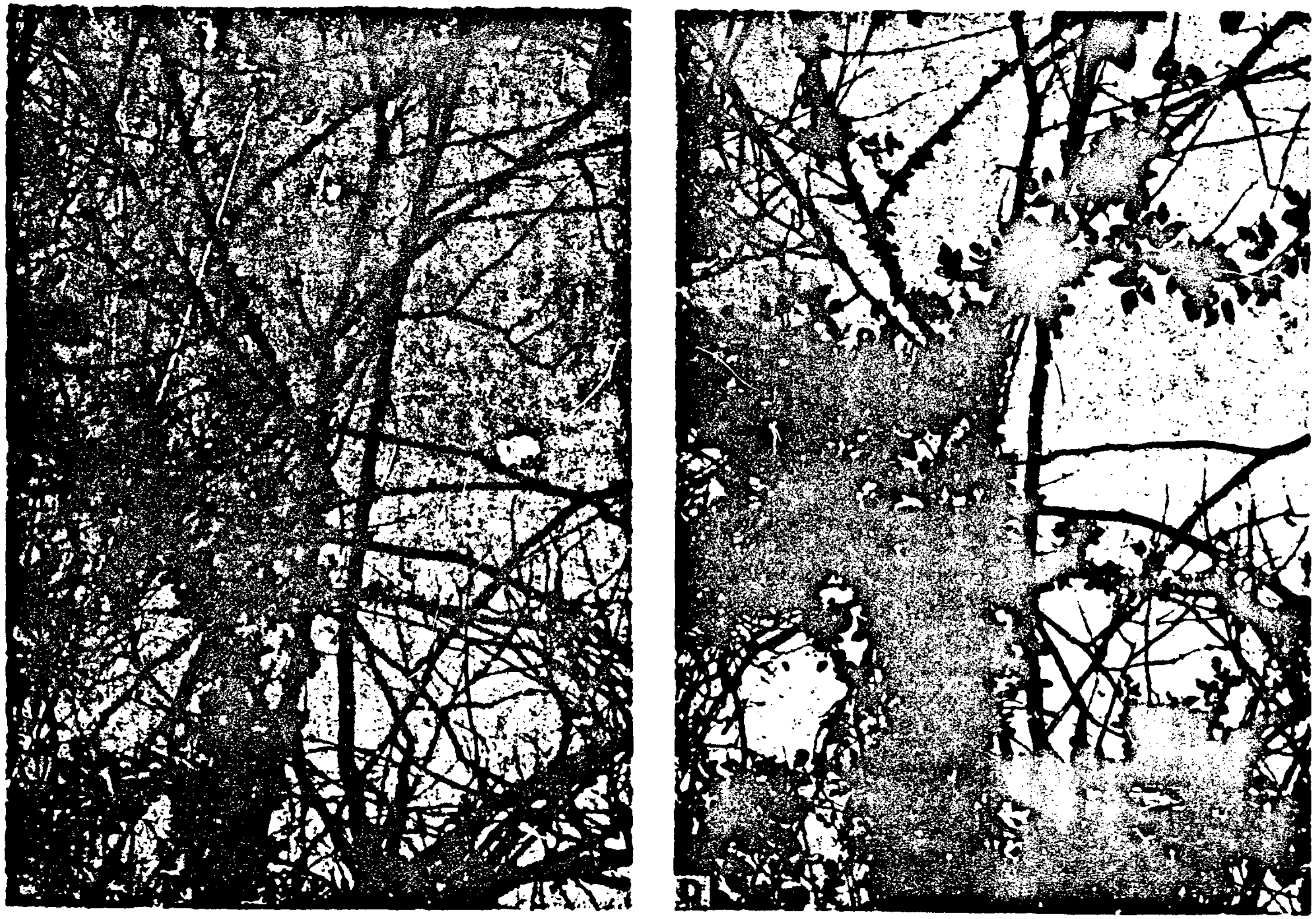


Figure 28. Defoliation Response from Orange Applied at 21 lb/acre on Test Site II.
A. Pretreatment, February 1965.
B. Two months after treatment.
C. Four months after treatment.
D. Seven months after treatment. No.e the regrowth of vines.

e. Remarks

Pink was generally superior to Purple in percentage of defoliation and in duration of effective defoliation based on visual estimates, vertical photography, and horizontal visibility techniques.

Detailed comparative analysis of effects of the two herbicides will be published in a subsequent report.

f. Recommendations

Pink can be applied for effective defoliation during the growing season at 1.5 gal/acre or 15 lb/acre acid equivalent.

4. Dinoxol

a. Chemical Name

50% butoxy ethanol ester of 2,4-D and 50% butoxy ethanol ester of 2,4,5-T

b. Test Record

Number of treatments: 3
Rates: 4.0 to 10.0 lb/acre
Volumes: 1.0 to 3.0 gal/acre
Season: late rainy season

c. Type of Chemical

Herbicide, similar to Purple

Commercial formulation, containing 4 lb/gal acid equivalent.

d. Treatment Effects

(1) Rate

Effective defoliation obtained on Test Site II at 10 lb/acre.

Slightly superior to Purple at lower rates tested.

(2) Volume

No direct comparisons made.

Volume of 3 gal/acre was superior to 1 gal/acre at respective rates of 6 and 4 lb/acre.

(3) Season

No comparisons made.

(4) Site

Two of three treatments were more effective on Test Site II.

e. Remarks

In the limited tests with this chemical, defoliation response was slightly superior to that of Purple. This formulation contains an oil base that may have enhanced absorption and penetration of the herbicide.

f. Recommendation

Additional testing desirable. Apparently equivalent in effectiveness to Purple or Orange.

5. Cacodylic Acid (Including sodium cacodylate - code name Blue)

a. Chemical Name

Dimethyl arsinic acid

Sodium salt of dimethyl arsinic acid

b. Test Record

Number of treatments: 5
Rates: 1.8 to 6.0 lb/acre
Volumes: 0.9 to 2.8 gal/acre
Seasons: early rainy, late rainy, and dry

c. Type of Chemical

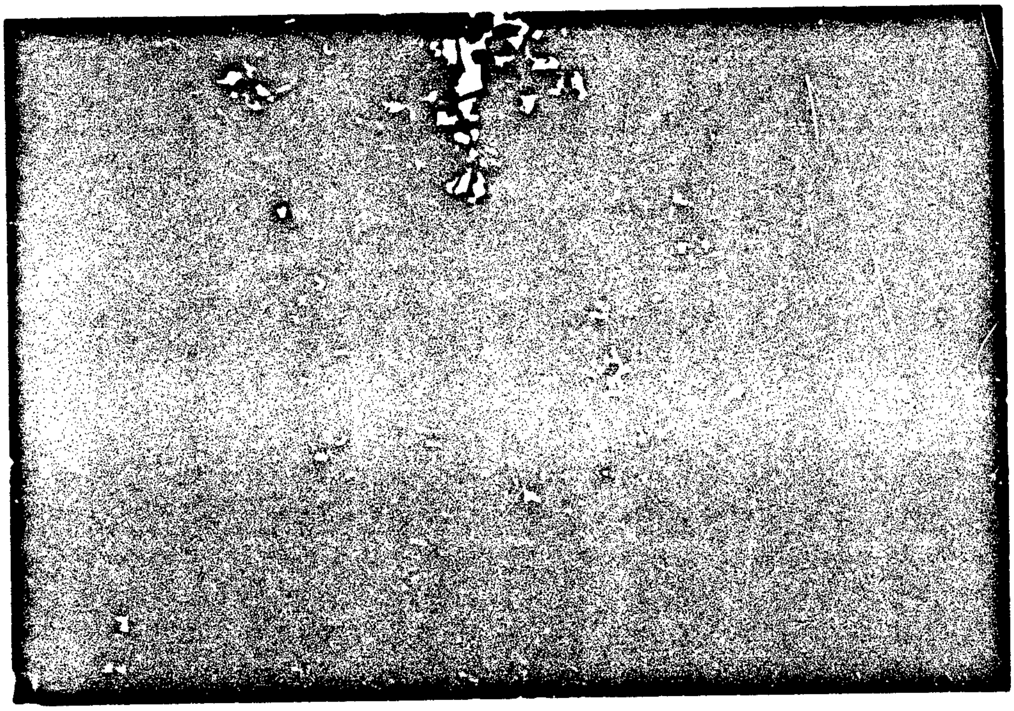
Desiccant, causing rapid defoliation.

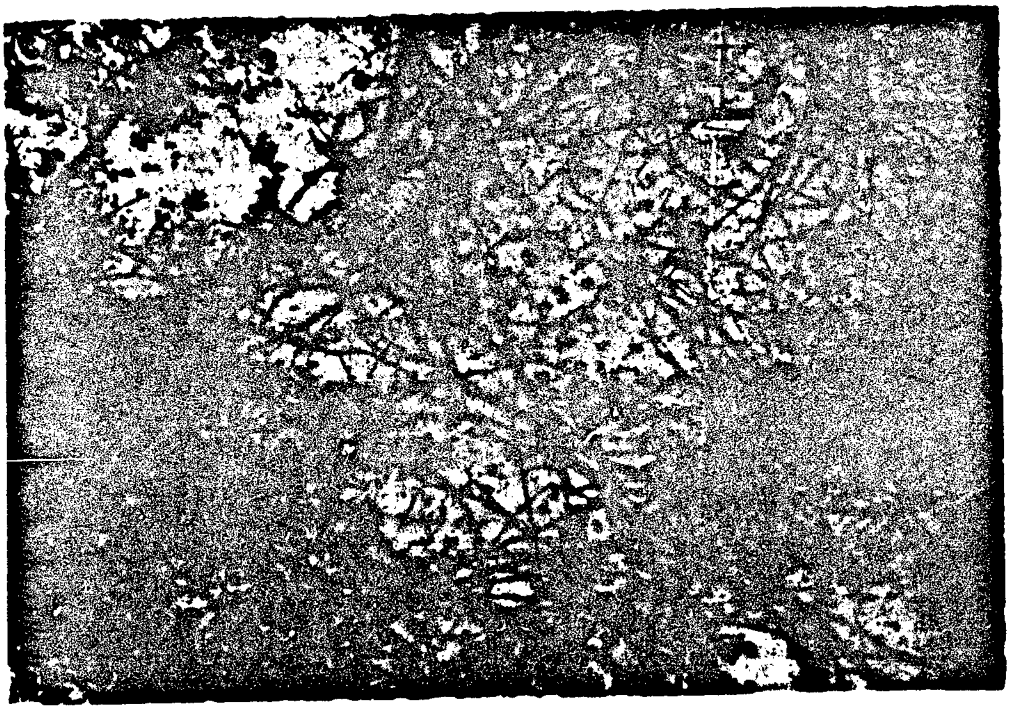
d. Treatment Effects

(1) Rate

Defoliation effective for a period of 2 to 4 weeks after treatment was obtained by applications of 3.5 to 6.0 lb/acre during both dry and rainy seasons. The higher rate of application was needed for effective defoliation on Test Site I (Figure 29).

Sodium cacodylate was tested only at the minimum rate but appeared to be comparable in effect to cacodylic acid.





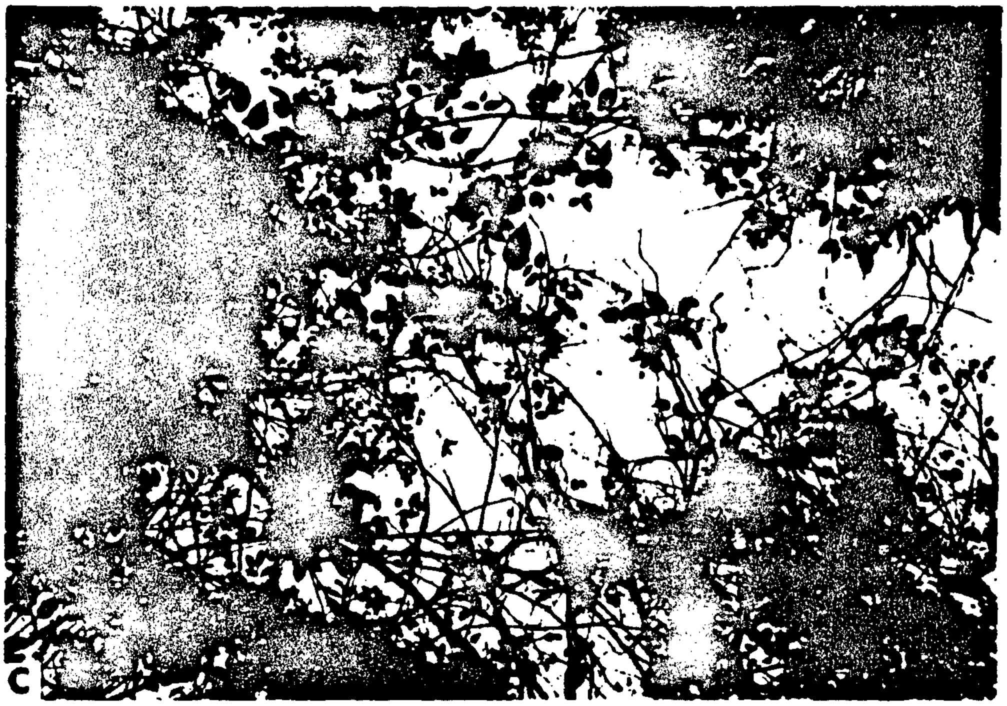


Figure 29. Defoliation Response from Cacodylic Acid Applied at 4.5 lb/acre at Test Site I.
A. Pretreatment, May 1964.
B. Three weeks after treatment at maximum effect.
C. Three months — showing regrowth.

(2) Volume

Spray volumes of 2 to 2.5 gal/acre are needed for adequate coverage.

(3) Seasons

Applications of 3.5 to 6.0 lb/acre were effective in either a dry or rainy season.

Regrowth occurred rapidly following rainy-season applications. Defoliation ratings of effective treatments were less than 50% 3 months after application.

(4) Site

Comparable results were obtained on the two test sites according to visual estimates. Improvement in horizontal visibility was greater on Test Site II.

e. Remarks

Both cacodylic acid and diquat were effective defoliants for short periods. A high percentage of leaf fall occurred in 1 or 2 weeks but vegetation recovered rapidly, particularly under favorable moisture conditions.

Cacodylic acid was effective in both dry- and rainy-season applications; diquat was effective in the growing season only.

Cacodylic acid produced slightly less defoliation of the upper canopy than diquat as evaluated by visual estimates and vertical photography. Cacodylic acid at 6.0 lb/acre gave defoliation response equivalent to Purple or Orange at 15 lb/acre.

Improvement in horizontal visibility obtained with cacodylic acid at rates of 1.8 to 6.0 lb/acre was equivalent to that of Purple or Orange applied at 2 to 3 gal/acre.

f. Recommendations

Cacodylic acid is recommended for rapid defoliation during the growing season or dry season. Applications of 5 to 6 lb/acre of cacodylic acid or sodium cacodylate in a volume of 2.5 to 3.0 gal/acre give effective defoliation.

6. Diquat

a. Chemical Name

1:1'Ethylene-2:2'dipyridylium dibromide

b. Test Record

Number of treatments: 6 with diquat alone; 1 in mixture with amitrole; 1 in mixture with Tordon
Rates: 2.2 to 5.0 lb/acre
Volumes: 1.1 to 3.0 gal/acre
Seasons: early rainy, late rainy, and dry

c. Type of Chemical

Desiccant, causing rapid defoliation

d. Treatment Effects

(1) Rate

Rates of 3 to 5 lb/acre were required for effective defoliation. Maximum effecc occurred 2 to 4 weeks following treatment.

Treatments in undisturbed forest vegetation of Te-- Site I were marginal in effectiveness at the maximum rate.

(2) Volume

Spray applications of 2.0 to 3.0 gal/acre gave adequate coverage in forest and secondary growth vegetation. Water was used as a diluent.

(3) Season

Diquat was effective during the growing season only. Dry-season treatments were ineffective at a 4 lb/acre rate.

A dry-season application of diquat at 4.8 lb/acre in mixture with 7.2 lb/acre of amitrole was ineffective.

(4) Site

Diquat was marginal in effectiveness on Test Site I but gave as much as 85% defoliation on Test Site II from late rainy-season applications at 5.0 lb/acre.

e. Remarks

Diquat caused rapid defoliation similar to that of cacodylic acid. Maximum effect was noted in 2 to 4 weeks but regrowth occurred rapidly.

Diquat gave slightly less improvement in horizontal visibility than cacodylic acid. As evaluated by vertical photography and visual estimates, the two chemicals gave equivalent response.

A mixture of diquat with Tordon at rates of 2.5 lb/acre and 1.2 lb/acre, respectively, was effective 3 to 5 months after treatment.

f. Recommendations

Diquat is an effective rapid-acting desiccant. Applications of 3 to 5 lb/acre give effective defoliation for a period of 2 to 4 weeks after treatment.

Diquat is comparable in effect and rate of action to cacodylic acid. The latter is preferred for use as a rapid defoliant.

Mixtures of Tordon and diquat should be given additional testing under similar site conditions.

7. Dicamba

a. Chemical Name

2-methoxy-3,6-dichlorobenzoic acid (Available as acid and amine salt)

b. Test Record

Number of treatments: 5
Rates: 3.9 to 15.0 lb/acre
Volumes: 1.3 to 3.4 gal/acre
Seasons: early rainy, late rainy, dry

c. Type of Chemical

Herbicide

d. Treatment Effects

(1) Rate

Dicamba acid applied in the dry season at 11 lb/acre in butanol-water emulsion gave apparent effective visual ratings for 5 months. Data indicated treatment was marginal or ineffective.

Dicamba amine applied at 15 lb/acre during early rainy season gave barely effective defoliation 4 to 5 months after treatment.

(2) Volume

Volume comparisons not available.

Three gallons per acre of water or emulsion sprays adequate for coverage.

(3) Season

Marginal response in rainy season; marginal to ineffective during the dry season.

(4) Site

Variable response; two of three treatments superior on Test Site II.

e. Remarks

Dicamba gave marginal defoliation response; inferior to Purple, Orange, or Pink.

Dicamba amine was readily applied in water.

Acid formulation is not soluble in water or oil and required butanol-water emulsion as solvent.

Not suitable for operational use.

f. Recommendations

Minimal in effectiveness at 15 lb/acre.

Inferior to Purple or Orange.

Amine formulation of possible use in additional tests in mixtures with cacodylic acid or other water-soluble chemicals.

8. Tordon

a. Chemical Name

4-amino-3,5,6-trichloropicolinic acid, available as potassium salt

b. Test Record

Number of treatments: 4
Rates: 2.8 lb/acre
1.2 lb/acre with 2.5 lb/acre diquat
2.3 lb/acre with 5.3 lb/acre 2,4-D amine
0.5 lb/acre with 9.1 lb/acre Orange
Volumes: 1.5 to 3.2 gal/acre
Seasons: Late rainy, dry, early rainy

c. Type of Chemical

Herbicide

d. Treatment Effects

(1) Rate

Tordon applied singly during dry season at 2.8 lb/acre gave marginally effective defoliation for 4 months; increased response was observed in the 5th month.

In combination with diquat, late rainy-season applications were effective from 3 to 5 months after treatment.

With 2,4-D, Tordon at 2.3 lb/acre was effective from 4 to 6 months after treatment; visual estimates of 80 to 90% defoliation were recorded at 5 months; maximum effect (78 to 79%) was observed by the photographic method at 2 to 5 months. The combination of 2,4-D and Tordon gave the greatest increase in horizontal visibility in the entire test program.

Tordon at 0.5 lb/acre with Orange (9.1 lb/acre) showed no significant difference in defoliation from Orange treatments lacking Tordon. Maximum effect was reached in 1 month.

(2) Volume

No significant comparisons can be made.

Volume of 3 gal/acre appears to be satisfactory.

(3) Season

Tordon applied during the dry season was marginally effective but showed an increase in effect at the end of 5 months.

Rainy-season applications of Tordon with 2,4-D and diquat were effective at rates used.

(4) Site

Three of four treatments were restricted to Test Site II. No significant comparisons.

e. Remarks

Tordon is a potent herbicide. Defoliation responses at 2.8 lb/acre were equivalent to treatments with Purple or Orange at 10 lb/acre.

The small amount of Tordon available severely limited the number of tests, and most treatments were made in combinations with other chemicals.

Herbicidal response to Tordon is slower than that from Purple or Orange, reaching maximum in 4 to 6 months.

f. Recommendations

Highly effective defoliation was obtained with the combination of 2 lb/acre Tordon and 5 lb/acre of 2,4-D amine in a single test.

An additional test of 1.2 lb/acre Tordon and 2.5 lb/acre diquat was effective for a 2- to 6-month period.

This chemical deserves additional testing when applied singly or in mixtures with other chemicals. Rates of 2 to 4 lb/acre are suggested.

9. Endothall

a. Chemical Name

3,6-endoxohexahydrophthalic acid

disodium 3,6-endoxohexahydrophthalate

b. Test Record

Number of treatments: 4 with Endothall salt
3 with Endothall acid
Rates: 1.0 to 5.5 lb/acre
Volumes: 1.2 to 4.0 gal/acre

c. Type of Chemical

Defoliant

d. Treatment Effects

(1) Rate

Maximum defoliation ratings obtained by visual estimates and vertical photography techniques were 30 to 50% at rates of 5 to 5.5 lb/acre.

Initial defoliation of 10 to 30% was recorded in the first 2 weeks after treatment. Maximal effect occurred 1 to 1.5 months after treatment.

(2) Volume

No comparisons of volume were made but 2.5 to 4.0 gal/acre gave satisfactory spray coverage.

(3) Season

No valid comparisons. Growing-season treatments gave maximum defoliation.

(4) Site

No valid comparisons.

e. Remarks

Treatments with Endothall were ineffective at rates up to 5.5 lb/acre.

Some species showed defoliation response within one week after treatment.

f. Recommendation

Not suitable as a defoliant under test site conditions.

10. Ineffective Chemicals

a. Amitrole

(1) Chemical Name

3-amino-1,2,4-triazole

(2) Test Record

Single treatment at 6.3 lb/acre

Additional treatment at 7.2 lb/acre in mixture with diquat at 4.8 lb/acre

(3) Type of Chemical

Herbicide, effective in control of certain woody plants.

(4) Remarks

Amitrole gave no recordable defoliation in applications at 6 lb/acre in late rainy season or in mixture with diquat in a dry-season application.

Slight chlorosis of the upper canopy foliage was apparent in aerial observations.

(5) Recommendation

Not effective.

b. Butyne diol

(1) Chemical Name

2-Butyne-1,4-diol

(2) Test Record

Three treatments at rates of 4.5 to 11.0 lb/acre during the early- and late-rainy seasons.

(3) Type of Chemical

Defoliant and desiccant.

(4) Remarks

Butyne diol was ineffective and resulted in only slight defoliation ratings at 3 to 4 weeks.

(5) Recommendation

Not effective.

c. Folex; Merphos

(1) Chemical Name

Tributyl phosphorotrithioite

Formulated as Merphos, an oil-soluble concentrate, and Folex, an emulsifiable concentrate.

(2) Test Record

Five treatments at rates of 6 to 28 lb/acre during the early- and late-rainy seasons.

(3) Type of Chemical

Defoliant

(4) Remarks

High rates of Merphos (22 and 28 lb/acre applied in diesel fuel) gave approximately 50 to 60% defoliation at 1 to 3 weeks as measured by the vertical obscuration techniques. Ratings by visual estimates did not exceed 15% defoliation.

Major effect was in the upper canopy layer.

(5) Recommendation

Not effective.

d. Tributyl Phosphate

(1) Chemical Name

Tributyl phosphate

(2) Test Record

Three treatments at rates of 10 to 24 lb/acre during the early- and late-rainy season.

(3) Type of Chemical

Desiccant.

(4) Remarks

Tributyl phosphate gave negligible defoliation within the first 2 weeks after treatment.

(5) Recommendation

Not effective.

XI. DISCUSSION

A. GENERAL RESPONSES TO DEFOLIANT CHEMICALS

General similarities were noted for the entire group of chemicals in the test program in response to several variables and conditions of the test.

1. Season of Application

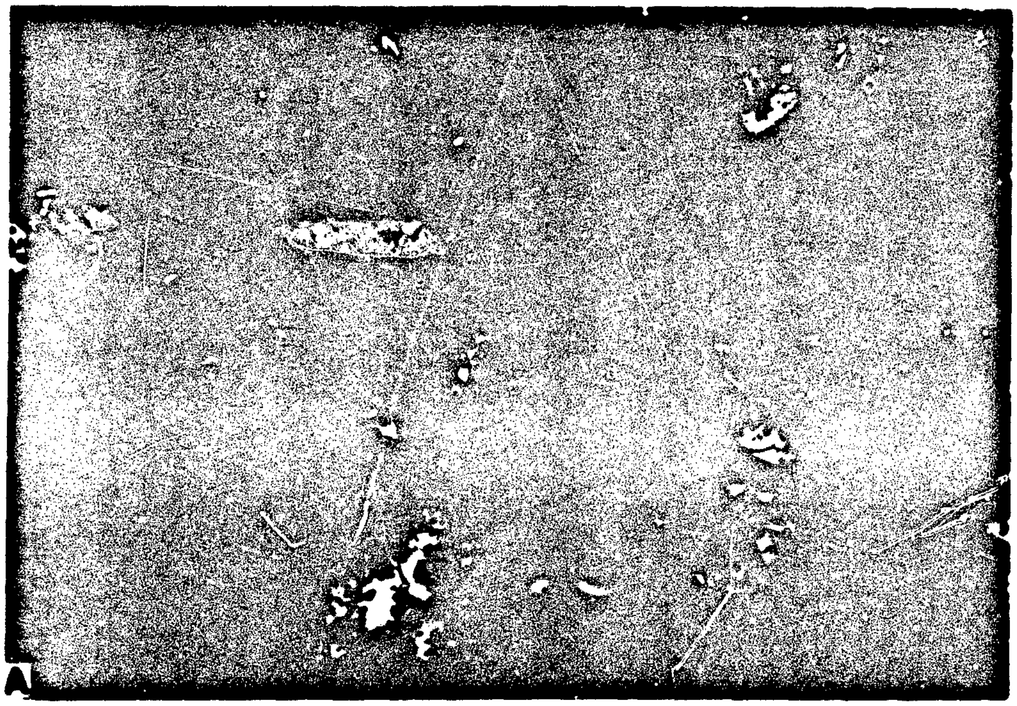
The season of application and the related climatic and soil moisture conditions were important variables affecting the responses of vegetation to chemical treatments. The monsoon rainy season that extends from May to November in the test area is normally a period of active growth of the dry evergreen forest (Figure 30).

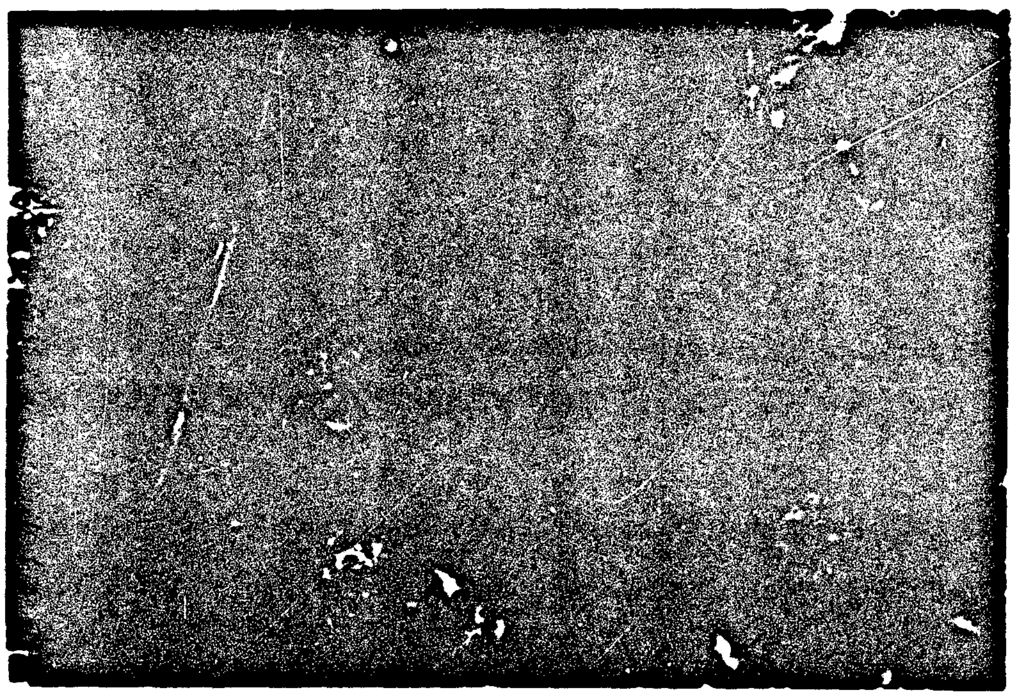
Purple, Pink, Orange and other growth-regulator herbicides gave more effective defoliation response from applications made during the rainy or growing season than in the dry season under conditions of deficient soil moisture for plant growth. This seasonal effect on defoliation was noted particularly on Test Site I on which dry-season applications of Purple were ineffective at rates up to 3.0 gal/acre. By contrast, applications of Purple at 1 gal/acre during the growing season gave effective defoliation at this site.

Natural defoliation of woody species was more evident on Test Site II during the dry season. Some of the relatively high defoliation ratings from the visual estimate technique obtained on this site in the dry season include the effects of both natural and chemically-induced defoliation (Figure 31).

The two desiccants, cacodylic acid and diquat, differed in their effectiveness in dry-season applications. Cacodylic acid was effective in both rainy- and dry-season treatments. Diquat appeared to be more effective when applied during the rainy season. Diquat has been demonstrated to exhibit limited translocation following foliar absorption, thus enhancing its action during periods of plant growth. Cacodylic acid, on the other hand, produced primarily a contact effect and was not appreciably influenced by the growth conditions of the plants.

The natural responses of vegetation cover to the cycles of dry and rainy seasons on the two test sites are shown in Figures 18, 30, and 31, as observed on untreated controls by the vertical photography technique. Greater amplitude of seasonal variation in canopy density is noted at Test Site II than in Test Site I. The vegetation in the latter site consisted of undisturbed forest with a more or less continuous intermediate tree layer of evergreen species under a scattered canopy of mixed evergreen and deciduous trees. On Test Site II the major species components were deciduous, resulting in marked seasonal changes in foliage density between the wet and dry seasons.





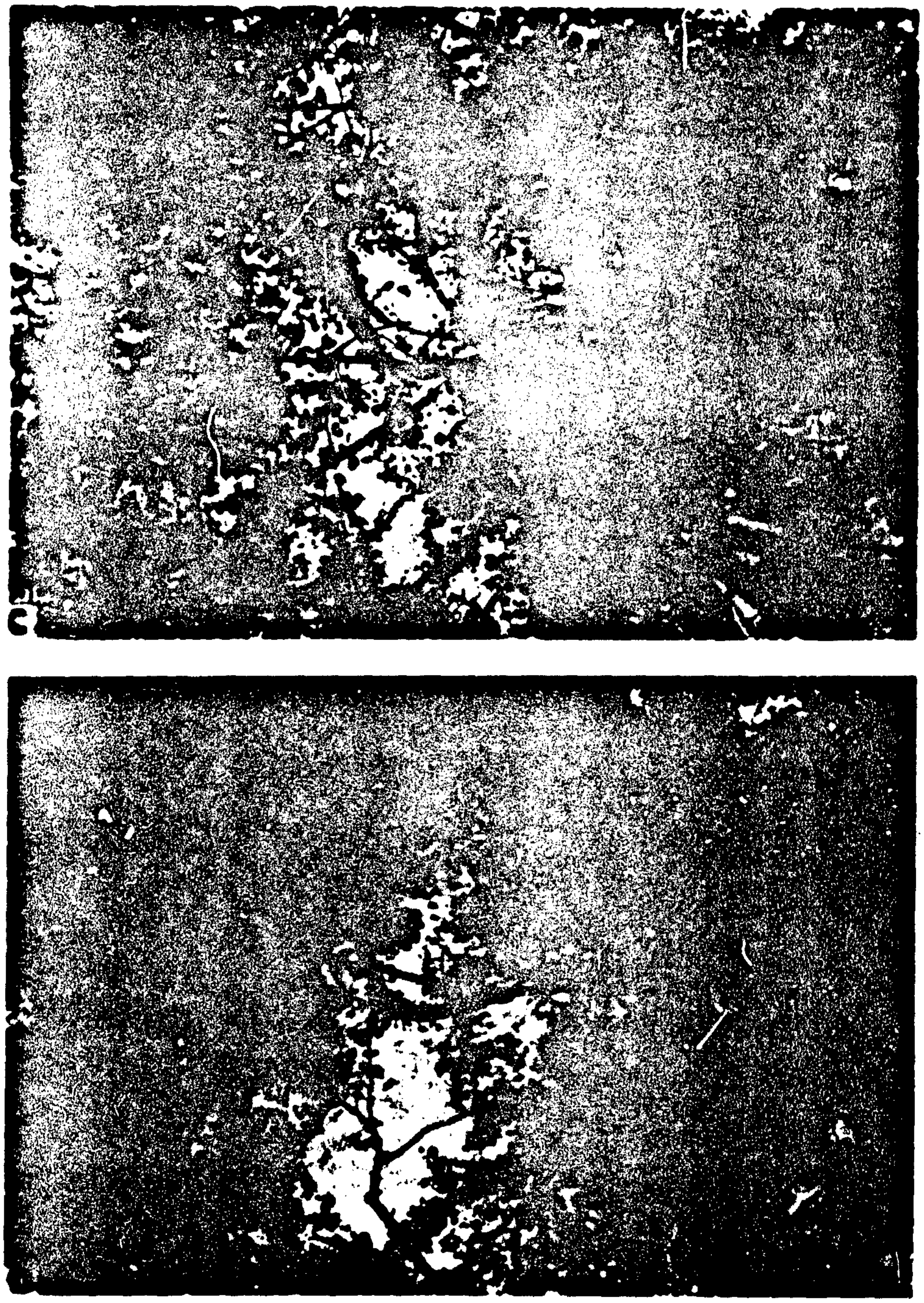


Figure 30. Seasonal Foliation Changes at Test Site I in an Untreated Control Plot.
A. Mid-rainy season, Sept 1964.
B. Early dry season, Jan 1965.
C. Late dry season, April 1965.
D. Early rainy season, June 1965.

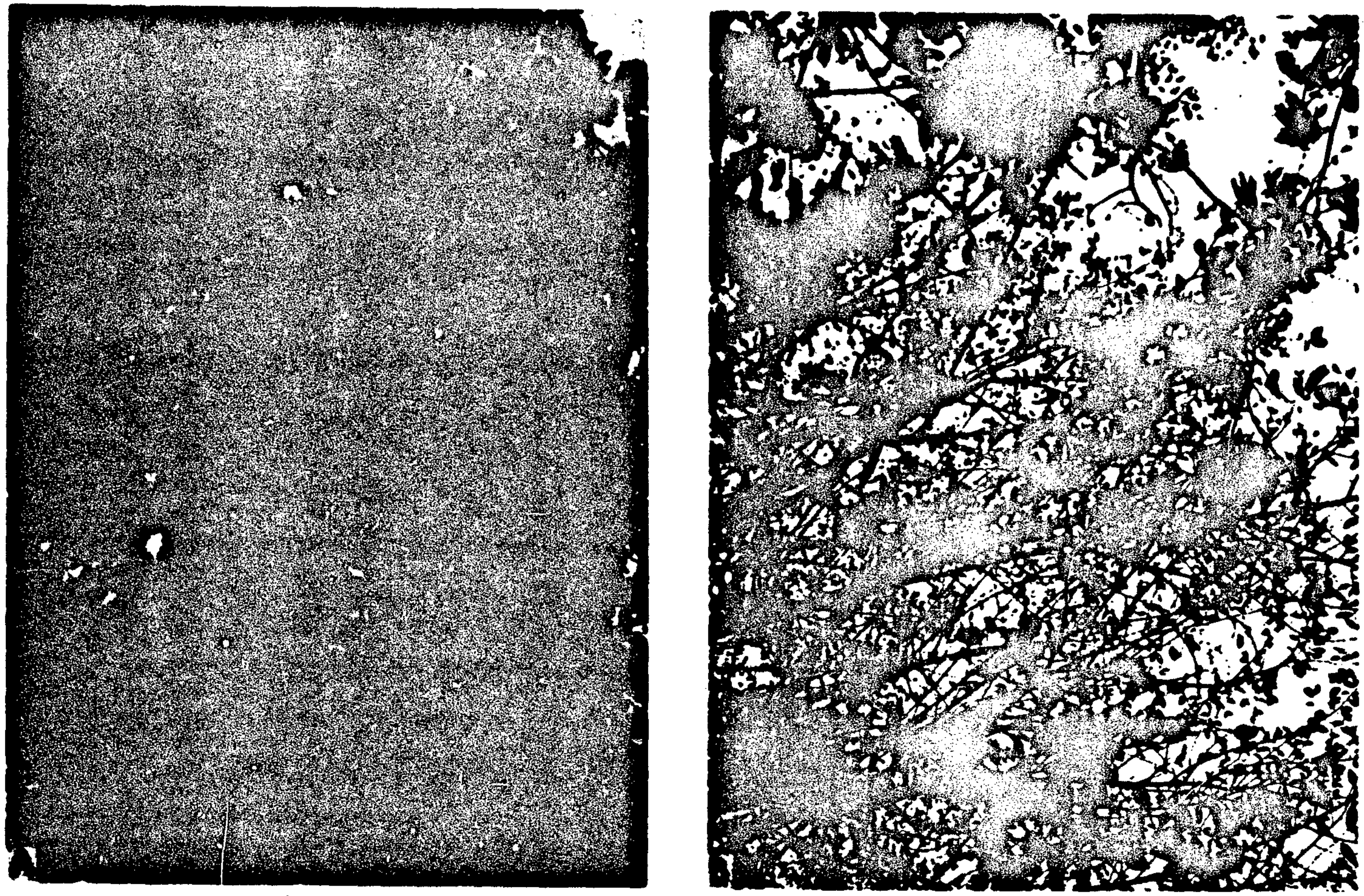


Figure 31. Seasonal Foliation Changes at Test Site II in an Untreated Control Plot.
A. Mid-rainy season, Sept 1964.
B. Late dry season, March 1965.

2. Site Differences

Fairly consistent differences were found between Test Sites I and II in the defoliation responses to most chemicals. Representative data illustrating these differences are shown in Table 12 for Purple, Pink, and cacodylic acid treatments. In 75 to 80% of the instances in which the same treatment was applied to plots on the two test sites, the response on Test Site II was greater.

TABLE 12. MEAN MAXIMUM DEFOLIATION RESPONSES ON TEST SITES I AND II FROM SELECTED TREATMENTS

Test Site	% Maximum Defoliation		Horizontal Visibility Increase Ratio
	Visual Estimate	Vertical Obscuration	
	Purple: Five Treatments, mean rate 16.9 lb/acre		
I	40	43	1.5
II	74	70	2.7
	Pink: Five Treatments, mean rate 10.4 lb/acre		
I	54	54	1.8
II	75	77	1.8
	Cacodylic Acid: Three Treatments, mean rate 3.7 lb/acre		
I	49	42	1.8
II	57	51	3.3

This difference in response was related to differences in the general structure, density, and species composition of the vegetation on the two sites and the relation of these characteristics to spray coverage and penetration. Test Site I consisted of forest with 2 or 3 layers or strata of trees and shrubs in the vegetation profile. A typical section or profile included the dominant canopy of broadly spreading tree crowns at varying heights and spacing, an intermediate tree layer of evergreen species such as Streblus zeylanica that showed resistance to treatment with most chemicals, and a dense shrub layer with many vines and woody climbers. Test Site II consisted of secondary forest or shrub vegetation in which the major tree cover had been removed by clearing and cutting. The major cover consisted of small trees and shrubs, usually more open and subject to greater penetration of spray during treatment application than the dense multilayered forest of Test Site I. As noted in the discussion on season of application, Test Site II contained a higher proportion of seasonally deciduous species that showed a greater response to chemical treatment than the predominant evergreen composition of Test Site I.

3. Species Response to Treatment

Marked differences in species defoliation response were noted in the diverse and complex plant population of the test sites. Species such as Acacia comosa, Phyllanthus sp. and Cleistanthus dasyphyllus defoliated readily from most chemical treatments. Trees including Streblus zeylanica, Hydnocarpus ilicifolius, and several species of Diospyros were relatively resistant to defoliation with the chemicals tested. A detailed analysis of species response will be published in a subsequent report.

In the more complex vegetation of Test Site I, differences were noted in the relative response of dominant canopy and of the shrub and ground cover layers, attributable in part to variations in amount of chemical spray deposited in the upper canopy vs. the forest floor and to possible differences in susceptibility of the species components to chemical treatment.

4. Rates and Volumes of Application

Chemicals such as Purple, Pink, Orange, and cacodylic acid that were tested at several rates generally showed an increase in defoliation effectiveness at the higher rates of application. Ineffective chemicals including Endothall and tributyl phosphorotrithioite (Folex and Merphos) exhibited partial defoliation response only at the higher rates tested.

Maximum defoliation responses of 85 to 90% were recorded but complete defoliation of all species was not obtained on any treatment plot.

Rate of chemical applied had a greater influence on effective defoliation than volume of spray solution applied. Evaluation of treatments with Purple, Orange, and Pink in which 1 gal/acre of pure chemical was compared with 2 gal/acre of a 1:1 mixture of chemical and diesel fuel showed no significant differences in defoliation response.

Application or delivery volumes of 1.5 to 3.0 gal/acre appeared to be adequate for Purple and other oil-soluble chemicals. Water-soluble chemicals such as cacodylic acid required a higher delivery volume to achieve desired levels of spray deposit because of droplet evaporation. Minimum delivery volumes of 2.5 to 3.0 gal/acre of these chemicals were needed to give satisfactory coverage and penetration of the canopy.

B. CRITERIA FOR EVALUATION

Evaluation of effectiveness of defoliation treatments in relation to type of chemical, rate, volume, and season of application was based principally on visual estimates and measurements of canopy obscuration by vertical photography. The photographic technique furnishes a more precise and quantitative measure than visual estimates.

In the visual estimate method, an over-all percentage of defoliation is obtained in which proportionate differences in defoliation in the several layers of the vegetation profile are combined by the observer into one value. In the vertical photography technique, the photographic sample of the vegetation profile assumes the form of an inverted cone with its tip at camera level. The 60-degree angle of the cone apex when projected upward encloses a circular area 50 feet in diameter at a height of approximately 45 feet. Thus, the sample size and the proportion of area sampled are greater in the dominant canopy than in the shrub layer. However, some compensation for the reduced sample size in the shrub layer is offered by the larger negative image of this profile component because of its proximity to the camera.

A [illegible]minary comparison of maximum-effect data from the photographic and vis[illegible]ate techniques shows a fairly high correlation between the two sets [illegible]s obtained. Mean values for 70 treatments were 69.3% for visua[illegible]tes vs. 63.1% for vertical obscuration values. The photograph[illegible]nique gives lower values than the visual-estimate method because of t[illegible] variable obscuration component contributed by the residual branches and tree trunks. Maximum values of 85 to 95% have been observed for both techniques, and the two methods may be considered fairly comparable in rating effectiveness of treatment.

Measurements of target visibility obtained by the horizontal visibility technique reflect variations in combined foliar density and obscuration to vision offered by the matrix of stems and branches. In the jungle-type vegetation of the test location, the reduction in horizontal visibility due to obscuration by stems and branches places a variable maximum limit on visibility at the distances used in the evaluation technique. This obscuration component is considerably greater in magnitude than that encountered in the vertical-obscuration technique and results in a narrower range of values from measurements before and after defoliation treatment. In the data analyzed, the extreme limits of horizontal visibility at a distance of 10 to 20 meters were 10% before treatment to 63% under maximum defoliation. Mean pretreatment visibility for 60 treatments on the two test sites was 24.6%.

Thus, improvement in visibility from defoliation treatment falls within a more restricted range of absolute values than is expressed by the other two techniques. Assuming an initial visibility of 25% and an upper limit of 75%, an observed target visibility rating of 60% would represent a net improvement of 35 ÷ 50 or 70%. Treatments rated effective by the visual-estimate method (60 to 65% or more) had horizontal visibility ratings of 45 to 50% at maximum effect (Table 12).

Visual estimates of 60 to 65% or more over-all defoliation are considered effective in improvement of air-ground visibility. General observations of vegetation response to treatment throughout the forest profile of Test Site I revealed that the upper or dominant canopy defoliated more readily than the intermediate tree and shrub or ground cover layers. This gradation in response from the uppermost layer to the forest floor was due to several factors including reduced spray deposit under heavy canopies and to differential response of species to chemical treatment. Assuming that the forest profile consisted of three strata, with one-third of the foliage density contributed by the dominant canopy, an over-all estimate of 65% defoliation generally represented an upper canopy defoliation of 80 to 85%. This degree of defoliation would greatly improve air-ground visibility.

C. INTERPOLATION OF RESULTS

The information and experience gained in this test program should be of value in application to other tropical areas such as those in the Republic of Viet Nam. The general correspondence in the two areas in vegetation type, climate, soils, and terrain indicates that similar defoliation response should be obtained in the two locations. Both areas are characterized by a tropical evergreen forest with a monsoon climate resulting in a pronounced seasonal separation into a rainy season and a dry season. Close similarities in vegetational composition have been noted with many identical species and a large number of identical genera occurring in both locations.

The two test sites are representative of the range of vegetational conditions in large portions of Southeast Asia. Vast areas of relatively undisturbed jungle or tropical evergreen forest with its multi-layered structure are exemplified by Test Site I. The secondary forest and dense shrub growth of Test Site II are characteristic of the vegetational trends common throughout tropical areas following partial clearing and shifting cultivation.

Although the selection of the test location in one of the drier portions of the tropical forest area of Thailand was governed largely by its availability for the test program, it is believed that the choice was a fortunate one in presenting the more difficult vegetation situations in which defoliation might be utilized. Because of the extremely pronounced seasonal trends of the test location, maximum defoliation responses were consistently obtained during the favorable soil-moisture conditions of the rainy season. Interpolation of the results of these tests to other areas with a more favorable moisture regime would indicate that chemical defoliation treatment should be equally or more effective than at the test location. It is believed that many of the drought-resistant species of the dry mixed-evergreen forest such as bamboo and Streblus are relatively resistant to defoliation treatments. Thus, the extreme conditions of the test location would lead to recommended treatments that should provide an ample safety factor when applied to other more favorable areas.

The spray-distribution equipment and the restricted application conditions of the test program differ slightly from the procedures used in an operational program. The refinements of the research test program with relatively small test plots required careful control of spray drift to permit valid comparisons of adjacent test plots. Applications were made at a relatively low flying height above the forest canopy to secure uniform spray deposition on a relatively narrow swath width. It is believed that these differences in operational procedure are not sufficient to influence the projection of the test program results for large-scale requirements.

XII. CONCLUSIONS AND RECOMMENDATIONS

The following general conclusions are drawn from the results of the test program on the basis of evaluations completed through August 1965. Minimum effective defoliation is considered to be 60 to 65% based on visual estimates and vertical obscuration technique. A synopsis of use recommendations from this information is shown in Table 13.

1) Purple, Orange, Pink, Dinoxol, and Tordon were effective herbicides for long-term defoliation. Dicamba gave marginal but generally ineffective defoliation.

2) Cacodylic acid and diquat were effective desiccants for fast, short-term defoliation.

3) Merphos or Folex, Endothall, tributyl phosphate, butyne diol, and amitrole were ineffective as defoliants.

4) Orange was equivalent to Purple in defoliation effectiveness. Rates specified for Purple are applicable to Orange on the basis of short-term observations.

5) Minimum effective rate of Purple and Orange was 2.0 gal/acre of total esters (15 lb/acre acid equivalent) applied during the rainy or growing season. Applications at this rate were effective in both dense forest with multiple canopies and secondary forest and shrub with a single canopy. Defoliation was effective for 4 to 6 months after treatment.

6) Applications of Purple and Orange at 1.5 gal/acre (10 lb/acre acid equivalent) were effective during the rainy season in secondary forest and shrub with light to moderate cover.

7) Applications of Purple and Orange at 2.5 to 3.0 gal/acre gave maximum defoliation in vegetation types ranging from light to dense cover. At 3.0 gal/acre effective defoliation was obtained for 6 to 9 or more months after treatment.

8) Applications of Purple, Orange, and other growth-regulator herbicides were less effective during the dry season than when made during the growing season. Applications of these chemicals should generally be restricted to the rainy season when soil moisture is available for growth and to the month immediately preceding the rainy season.

9) Pink gave effective defoliation at slightly lower rates than Purple or Orange. Applications of Pink at 2.0 gal/acre during the rainy season gave effective defoliation for 8 to 9 months.

TABLE 13. CHART OF RECOMMENDATIONS

Defoliation Requirement	Chemical	Rainy Season		Dry Season	
		Light to Moderate Cover (Single Canopy)	Dense Cover (Multiple Canopy)	Light to Moderate Cover (Single Canopy)	Dense Cover (Multiple Canopy)
Fast, Short-Term Defoliation or Desiccation	Cacodylic Acid	5 to 6 lb/acre in 2.5 to 3.0 gal spray Equal to Blue (65% cacodylic acid) at 7.7 to 9.2 lb/acre	5 to 6 lb/acre in 2.5 to 3.0 gal spray Repeat application may be needed in 2 to 3 weeks for effective defoliation at ground level	5 to 6 lb/acre in 2.5 to 3.0 gal spray Equal to Blue (65% cacodylic acid) at 7.7 to 9.2 lb/acre	5 to 6 lb/acre in 2.5 to 3.0 gal spray Repeat application may be needed in 3 to 4 weeks for effective defoliation at ground level
Effective Defoliation (60 to 75%) for Moderate Duration, 3 to 4 months	Purple or Orange	1.5 to 2.0 gal/acre undiluted or in 1:1 mixture with diesel fuel	2.0 to 2.5 gal/acre undiluted Repeat application may be needed after 2 months	2.5 to 3.0 gal/acre undiluted	2.5 to 3.0 gal/acre undiluted
Maximum Defoliation and Duration, 6 months or more	Purple or Orange	2.5 to 3.0 gal/acre undiluted	2.5 to 3.0 gal/acre undiluted Repeat application may be needed after 2 months	2.5 to 3.0 gal/acre undiluted	3.0 or more gal/acre undiluted Repeat application may be needed in following rainy season

10) Minimum effective dosage of Pink appeared to be 1.0 to 1.25 gal/acre (8 to 10 lb/acre).

11) Dinoxol, a commercial formulation containing low-volatile esters of 2,4-D and 2,4,5-T, gave slightly superior defoliation response than Purple in limited trials. Additional comparative tests with Orange or Purple are needed to substantiate these results.

12) Cacodylic acid or sodium cacodylate applied in water solutions at rates of 5 to 6 lb/acre gave effective desiccation and defoliation of undisturbed forest and secondary forest and shrub vegetation. Maximum defoliation occurred 2 to 4 weeks after application. Treatments were equally effective during rainy and dry seasons.

13) Cacodylic acid applied at 6.0 lb/acre gave defoliation response equivalent to Purple or Orange at 15 lb/acre acid equivalent.

14) Diquat was equivalent in defoliation response to cacodylic acid or sodium cacodylate but was effective only during the growing season. Rates of 3 to 5 lb/acre were required for effective defoliation.

15) Dicamba gave minimal effective defoliation when applied at rates up to 15 lb/acre. The chemical was inferior to Purple, Orange, and Pink for long-term defoliation.

16) Limited tests showed that Tordon applied singly or in mixtures with 2,4-D, diquat, and Orange was highly effective on a per-pound basis but generally slower than Purple or Orange in defoliation response. Effective defoliation was obtained with Tordon in mixtures at rates of 1 to 3 lb/acre. Additional tests are needed to confirm these results.

17) Dry-season application of Tordon was marginally effective but showed an increase in effect at the end of 5 months.

18) All effective desiccants and herbicides gave a higher degree and a longer duration of defoliation with increased rate of application.

19) Defoliation responses from Purple, Orange, and Pink were influenced more by rate of application than by the volume of spray solution applied. Comparative treatments of these chemicals at 1 gal/acre of pure chemical with 2 gal/acre of a 1:1 mixture with diesel fuel showed no significant difference in defoliation response at the higher volume. The same amount of Pink applied in 2 gal/acre vs. 6 gal/acre of spray solution gave no difference in defoliation response.

20) Minimal volume of 1.5 gal/acre is recommended for applications of Purple, Orange, and other oil-soluble herbicides to secure effective spray coverage and penetration.

21) Wa ar-soluble chemicals such as cacodylic acid or diquat require a minimum volume of 2.5 to 3.0 gal/acre to achieve desired levels of spray deposit for effective coverage and penetration.

22) Optimum droplet sizes for rapid fallout and best penetration of vegetation canopy were in the range of 275 to 350 microns MMD for aerial spray application of Purple, Orange, and other defoliation chemicals.

23) Dry-season applications of Purple, Orange, and Pink at relatively high rates (2.5 to 3.0 gal/acre) gave apparently effective defoliation in light to moderate vegetation cover of secondary forest and shrub. Natural defoliation during the dry season contributed in varying ree to the high evaluation ratings obtained. Dry-season applications were nerally not effective in the dense forest type characterized by a small amount of natural seasonal defoliation.

24) Consistent differences in defoliation effectiveness were obtained on the two test sites characterized by (i) dense, semi-evergreen forest with a multiple canopy, and (ii) secondary forest and shrub with a single canopy. The more effective ratings obtained on the secondary forest type were attributed to the greater ease of spray penetration and to a higher proportion of plant species susceptible to chemical defoliation.

25) In dense forest vegetation with multiple canopy, the highest degree of defoliation from effective chemicals occurred in the upper or dominant canopy. Ground cover and shrub layers showed the least defoliation.

26) Complete defoliation of all vegetation components was not obtained with any of the chemicals tested in single applications. Maximum defoliation was assessed at 85 to 90%.

27) Marked differences in defoliation response to any chemical treatment occurred within the species composition of any layer of the forest vegetation. Some species defoliated completely; others showed little or no effect.

28) The duration of maximum defoliation effectiveness was governed by several factors, chief of which were: (i) amount and rate of regrowth of treated vegetation following defoliation, and (ii) amount and growth rate of weedy plants, vines, and other replacement vegetation following defoliation.

29) To prolong the duration of effective defoliation and to secure more effective spray penetration and defoliation of dense forest type with multiple canopy, repeat applications of Purple, Orange, cacodylic acid or other effective chemicals may be used. Results of limited tests of repeat applications in the current program will be evaluated in the final report. Suggested minimal intervals for repeat applications for increased effectiveness and duration are: (i) 2 to 4 weeks after initial application of

cacodylic acid; and (ii) 2 months after initial application of Purple, Orange, and other growth-regulator herbicides.

30) Visual estimates of defoliation were closely comparable to quantitative measurements obtained by the canopy obscuration technique employing vertical photographs.

31) Horizontal visibility measurements gave lower defoliation values than visual estimates or the vertical obscuration technique. Changes in horizontal visibility due to chemical treatment were dependent primarily on the degree of defoliation sustained by the shrub vegetation layer.

32) The results of the defoliation test program are generally applicable to the Republic of Viet Nam and adjoining areas of Southeast Asia.

It is recommended that additional field tests and studies on chemical defoliation be conducted in Thailand or similar tropical areas to meet the following objectives and requirements:

1) Evaluation of Orange and cacodylic acid or sodium cacodylate in several vegetation types including tropical evergreen rain forest, hill evergreen forest, secondary forest and shrub with high densities of tropical grasses such as elephant grass, cogon grass, and bamboo-dominated areas.

2) Evaluation of Pink, Tordon, and other herbicides in comparison with Orange and cacodylic acid in several vegetation types.

3) Evaluation of chemical mixtures including Orange and Tordon and other chemicals to secure enhancement of defoliation response and a broader spectrum of species subject to defoliation and topkill.

4) Evaluation of repeat treatments with Orange, cacodylic acid, and other chemicals to secure prolonged defoliation in vegetation types or under conditions in which regrowth occurs from single applications.

5) Evaluation of soil sterilants, herbicides, and desiccants for complete vegetation control of woody and grass vegetation in proximity to military encampments, boundary zones, transportation routes, etc.

6) Improvement of evaluation techniques including the development of a simpler system of horizontal visibility measurement than the "dot-count" method and in the refinement and simplification of the vertical photography technique.

Such programs should be conducted in areas such as Thailand where logistic support and interdisciplinary scientific cooperation may be obtained.

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APPENDIX A

CHEMICALS USED IN TEST PROGRAM

A. HERBICIDES

1. Purple

a. Chemical Name

Mixture consisting of

50% n-butyl ester of 2,4-dichlorophenoxyacetic acid
30% n-butyl ester of 2,4,5-trichlorophenoxyacetic acid
20% iso-butyl ester of 2,4,5-trichlorophenoxyacetic acid.

b. Physical and Chemical Properties

Liquid, soluble in diesel fuel.

c. Active Ingredient Content

98 to 100% active ingredient as total ester.
8.6 lb/gal acid equivalent.

d. Total Amount and Cost of Chemical

6000 gal; $6.50/gal; $39,000 total cost.

2. Orange

a. Chemical Name

Mixture consisting of

50% n-butyl ester of 2,4-dichlorophenoxyacetic acid
50% n-butyl ester of 2,4,5-trichlorophenoxyacetic acid.

b. Physical and Chemical Properties

Liquid, soluble in diesel fuel.

c. Active Ingredient Content

98% to 100% active ingredient as total ester.
8.6 lb/gal acid equivalent.

d. Total Amount and Cost of Chemical

825 gal; $7.00/gal; $5775 total cost.

3. Pink

a. Chemical Name

Mixture consisting of

60% *n*-butyl ester and 40% iso-butyl ester of 2,4,5-trichlorophenoxyacetic acid.

b. Physical and Chemical Properties

Liquid, soluble in diesel fuel.

c. Active Ingredient Content

98 to 100% active ingredient as total ester.
8-9 lb/gal acid equivalent.

d. Total Amount and Cost of Chemical

3800 gal; $10.00/gal; $38,000 total cost.

4. Dinoxol

a. Chemical Name

Commercial formulation consisting of

31.6% butoxy ethanol ester of 2,4-dichlorophenoxyacetic acid.
30.3% butoxy ethanol ester of 2,4,5-trichlorophenoxyacetic acid.

b. Physical and Chemical Properties

Liquid, soluble in diesel fuel.

c. Active Ingredient Content

2 lb/gal of 2,4-D; 2 lb/gal of 2,4,5-T acid equivalent.

d. Total Amount and Cost of Chemical

275 gal; experimental material donated by American Chemical Products, Inc., Ambler, Pennsylvania.

5. Dicamba

a. Chemical Name

2-methoxy-3,6-dichlorobenzoic acid (available as pure acid and dimethylamine salt).

b. Physical and Chemical Properties

Acid is a solid, soluble in butanol.
Amine formulated as a liquid, soluble in water.

c. Active Ingredient Content

Acid—95 to 100% active ingredient.
Amine—6 lb/gal active ingredient.

d. Total Amount and Cost of Chemical

Acid—2000 lb; \$4.50/lb; \$9000 total cost
Amine—240 gal; \$27.50/gal; \$6000 total cost

6. Tordon

a. Chemical Name

4-amino-3,5,6-trichloropicolinic acid; picloram
Formulated as potassium salt and amine (experimental).

b. Physical and Chemical Properties

Potassium salt and amine formulated in liquid, miscible with water.

c. Active Ingredient Content

2.0 lb/gal as potassium salt (Tordon 22K).
3.0 lb/gal in experimental amine formulation.

d. Total Amount and Cost of Chemical

Amine—40 gal; experimental material donated by Dow Chemical Co., Midland, Michigan.

Potassium salt—55 gal; experimental material donated by Dow Chemical Co., Midland, Michigan.

B. DESICCANTS AND DEFOLIANTS

1. Cacodylic Acid and Sodium Cacodylate

a. Chemical Name

Dimethyl arsinic acid.
Sodium salt of dimethyl arsinic acid.

b. Physical and Chemical Properties

White powder, soluble in water.

c. Active Ingredient Content

Cacodylic acid, 65% active ingredient.
Sodium cacodylate, 70% active ingredient.

d. Total Amount and Cost of Chemical

Cacodylic acid—1600 lb; \$1.75/lb; \$2800 total cost.
Sodium cacodylate—800 lb; \$1.85/lb; \$1480 total cost.

2. Diquat

a. Chemical Name

1:1'-ethylene-2:2'-dipyridylium dibromide.

b. Physical and Chemical Properties

Liquid formulation, soluble in water.

c. Active Ingredient Content

2 lb/gal of cation (bromide).

d. Total Amount and Cost of Chemical

720 gal; \$20.85/gal; \$15,012 total cost.

3. Endothall Acid and Salt

a. Chemical Name

3,6-endoxohexahydrophthalic acid.
Disodium 3,6-endoxohexahydrophthalate.

b. Physical and Chemical Properties

Acid—solid, soluble in dimethylformamide—water emulsion.
Salt—liquid, soluble in water.

c. Active Ingredient Content

Acid—100% active ingredient.
Salt—1.8 lb/gal active ingredient.

d. Total Amount and Cost of Chemical

Acid—1125 lb; $3.60/lb; $4050 total cost.
Salt—300 gal; $5.70/gal; $1710 total cost.

4. Merphos and Folex

a. Chemical Name

Tributyl phosphorotrithioite

b. Physical and Chemical Properties

Merphos—liquid, oil-soluble formulation.
Folex—liquid, miscible with water or diesel fuel.

c. Active Ingredient Content

Merphos—7.2 lb/gal active ingredient.
Folex—6.0 lb/gal active ingredient.

d. Total Amount and Cost of Chemical

Merphos—1375 gal; $7.60/gal; $10,450 total cost.
Folex—330 gal; $5.32/gal; $1920 total cost.

5. Amitrole

a. Chemical Name

3-amino-1,2,4-triazole

b. Physical and Chemical Properties

Crystalline solid, soluble in water.

c. Active Ingredient Content

80% active ingredient.

d. Total Amount and Cost of Chemical

1200 lb; \$2.65/lb; \$3180 total cost.

6. Butyne Diol

a. Chemical Name

2-butyne-1,4-diol

b. Physical and Chemical Properties

Solid, soluble in water.

c. Active Ingredient Content

95% active ingredient.

d. Total Amount and Cost of Chemical

2760 lb; \$0.60/lb; \$1656 total cost.

7. Tributyl Phosphate

a. Chemical Name

Tributyl phosphate.

b. Physical and Chemical Properties

Liquid, soluble in diesel fuel.

c. Active Ingredient Content

8 lb/gal of active ingredient.

d. Total Amount and Cost of Chemical

4000 lb; \$0.60/lb; \$2400 total cost.

APPENDIX B

SPECIFICATIONS OF AERIAL SPRAY DISTRIBUTION SYSTEM

A. TANK

A capacity of 180 gallons, box-shaped with rectangular sides, stainless steel; with internal baffle plates, 1½-inch inlet at base of tank connected through a line filter to quick-connect coupling on external fuselage, additional 3-inch tank inlet at top of tank, and 1½-inch air vent and overflow tube with outlet at bottom of fuselage. Equipped with external sight gauge calibrated in 5-gallon increments mounted on tank and liquidometer with gauge for indicating level in pilot compartment.

B. PUMP

Air-driven, AGAVENCO Model 6100 E 5, with five-bladed propeller, variable pitch blades, 2½-inch suction intake and 2-inch outlet connections. Equipped with brake operated from pilot compartment for control during flight.

C. BOOM AND NOZZLE ASSEMBLY

Two 20-foot, aluminum, streamlined, Sorenson 1½-inch booms mounted below wings forward of flaps. Tapped on trailing edge and bottom at 6-inch spacings for ¼-inch nozzles. Hose connections Teflon-lined on 2-inch pipes to tank, pump, and bypass.

D. NOZZLES

One-quarter-inch, brass, diaphragm jet (TEEJET No. 4664), with disc-type orifice and core, fitted with 50- or 100-mesh strainers.

E. CONTROLS

Control lever for boom system mounted at pilot compartment bulkhead. Positive three-way cutoff valve with suction pressure on boom in off position to prevent nozzle drip. Pressure regulation by gate valve on line from pump to boom, pressure gauge mounted on cockpit instrument panel.

F. BOOM AND NOZZLE CONFIGURATIONS USED IN TEST PROGRAM

1. 2 April to 12 May 1964

a. Boom

Twenty feet long, under wings only, mounted 10 to 16 inches below lower wing surface, taps for nozzles on lower surface.

b. Nozzle Placement, Number, Spacing, Direction, and Orifice

Inboard, 16 to 20 at 6-inch spacing, 90 degrees, D_7 and/or D_{10} orifice.

2. 12 May to 15 June 1964

a. Boom

Wing booms connected into single boom, 32 feet long, with nozzle positions under fuselage, mounted 23 inches below bottom of fuselage and lower wing surfaces, nozzle tap openings on upper surface to eliminate sediment accumulation.

b. Nozzle Placement, Number, Spacing, Direction, and Orifice (From center of fuselage to wing tip)

Under fuselage, five at 3-inch spacing, 45 degrees, D_{16} orifice.

Lateral to fuselage, four at 4-inch spacing, 45 degrees, D_{14} orifice.

Inboard, 12 or 13 at 6-inch spacing, 90 degrees, D_{10} orifice.

Outboard, two at 18-inch spacing, 90 degrees, D_8 orifice.

Boom tip, one, 45 degrees, D_6 orifice.

3. 15 June 1964 to 18 March 1965

a. Boom

Same as 2, a.

b. Nozzle Placement, Number, Spacing, Direction, and Orifice (From center of fuselage to wing tip)

Under fuselage, five at 3-inch spacing, 45 degrees, ¼-inch orifice.

Lateral to fuselage, four at 4-inch spacing, 45 degrees, ¼-inch orifice.

Inboard, six at 6-inch spacing, 90 degrees, ¼-inch orifice.

Outboard, one D_{10} orifice, two D_8 orifice, one D_6 orifice at six-inch spacing, 90 degrees.

Boom tip, one, 45 degrees, D_6 orifice.

4. 18 March to 4 June 1965

a. Boom

Same as 2, a.

b. Nozzle Placement, Number, Spacing, Direction, and Orifice (From center of fuselage to wing tip)

Under fuselage, three or four, at 3-inch spacing, 45 degrees, D_{16} orifice.

Lateral to fuselage, three or four at 4-inch spacing, 45 degrees, D_{14} orifice.

Inboard, six at 12-inch spacing, 90 degrees, D_{10} orifice.

Outboard, three at 18-inch spacing, 90 degrees, D_8 orifice.

Outboard, one at 24-inch spacing, 90 degrees, D_6 orifice.

Boom tip, one, 45 degrees, D_6 orifice.

APPENDIX C

DETERMINATION OF SPRAY DEPOSIT VOLUME, SWATH WIDTH, AND DROPLET SIZE

Characteristics of spray deposition including mass deposit, swath width, and percentage recovery of delivered spray volumes were obtained from grid calibration flights accompanying each treatment. The wet-plate method was used in calibrations; mass deposit values were obtained by colorimetric analysis based on a dye added to the spray solution. Droplet size as mass median diameter was obtained from Kromecote cards in matching series with the wet-plate samples.

DuPont Oil Red dye was used in spray mixes with Purple and other oil-soluble chemicals. Rhodamine Blue and Acid Orange dyes were used in water solutions of chemicals. Dye concentration was 0.1% by weight in the spray mixtures or 4 grams per gallon. DuPont Oil Red gave an absorbance peak of 515 millimicrons on the spectrophotometer.*

A. MASS DEPOSIT

Measurement of mass deposit at each sampling station on a grid line involved the use of the wet-plate technique with 6- by 6-inch sample plates of aluminum or stainless steel. Matching Kromecote card samples were examined to determine the limits of swath deposit. The wet-plate colorimetric analysis was performed only on this series of station samples plus an extra one at each end.

Each wet plate and its protection cover plate were placed on a rack designed to permit simultaneous washing of the two plates and the collection of washings in a single 25-ml volumetric flask. The solvents used were acetone for oil-soluble chemicals and water for water-soluble chemicals. The rinsings were brought up to uniform volume with additional solvent.

A calibration curve was prepared from duplicate samples of the original spray mixture taken after the day's flight. The dilution scheme for the calibration samples is shown in the diagram:

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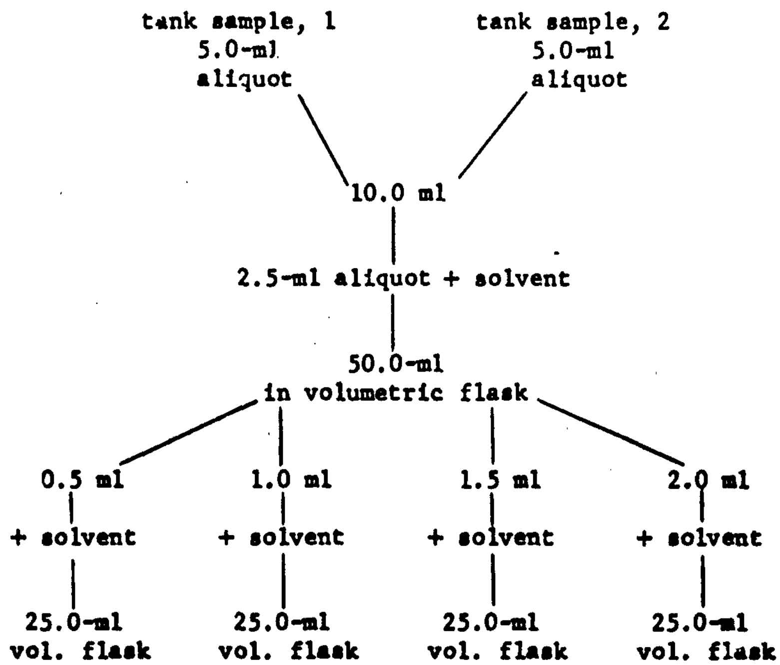
* Beyer, L.W.; Brown, J.W. 1964. Calibration of spray systems C-123/MC-1, H-34/HIDAL, A-1H/FIDAL, (Technical Report 46). (Sponsored by Advanced Research Projects Agency, Project Agile, ARPA Order 256). Crops Division, U.S. Army Biological Laboratories, Fort Detrick, Maryland.



A cuvette of the colorimeter was then filled from each of the four flasks and the respective transmittances were measured. The readings were plotted on a graph of percentage transmittance against gallons of spray volume per acre.

The standardization of the Bausch and Lomb Model 20 spectrophotometer used in these determinations was checked at intervals as a precaution against electrical drift due to surges in line voltage.

Following calibration of the colorimeter to the day's spray mix, the samples from the grid deposit plates were transferred directly from the volumetric flasks to cuvettes and tested twice for transmittance. The data for each series of samples were recorded on SMUFD Form 546 (Temp) (9 Apr 63). Each datum was then converted from percentage transmittance to estimated deposit in gallons per acre from the calibration curve and recorded on SMUFD Form 547 (Temp) (9 April 1963).

The mass deposit data were then plotted graphically on SMUFD Form 634 (Test) (Dec 63) and the points connected to form a contour curve depicting the deposit pattern.

RAW DATA SHEET

Date 24 Feb 1965
Material 1:1 Purple
Flight 1
Sample Line B

Spec. 20
Spec. Oper. KWA
Standard 23 @ 10
Fade Loss

Sta	% Transmittance			Avg	Sta	% Transmittance			Avg	Sta	% Transmittance			Avg
1					34	63	63			67				
2					35	80	80			68				
3					36	89	89			69				
4					37	89	89			70				
5					38	94	94			71				
6					39	96	96			72				
7					40	97	97			73				
8					41	99	99			74				
9					42	99	99			75				
10					43	98	98			76				
11					44	98	98			77				
12					45	100	100			78				
13					46	100	100			79				
14					47	100	100			80				
15					48	100	100			81				
16	100	100			49					82				
17	99	99			50					83				
18	99	99			51					84				
19	93	93			52					85				
20	92	92			53					86				
21	94	94			54					87				
22	89	89			55					88				
23	85	85			56					89				
24	83	83			57					90				
25	70	70			58					91				
26	71	71			59					92				
27	76	76			60					93				
28	77	77			61					94				
29	62	62			62					95				
30	68	68			63					96				
31	72	72			64					97				
32	61	61			65					98				
33					66					99				
F P										100				

SMUFD Form 546 (Temp) (9 Apr 63)

MASS DEPOSIT

Material 1:1 Purple
Date 24 Feb 1965
Flight 1
Sample Line B
Time of Release 0643
Duration 7.0
Flow Rate 686 PM @ 58 PSI
System

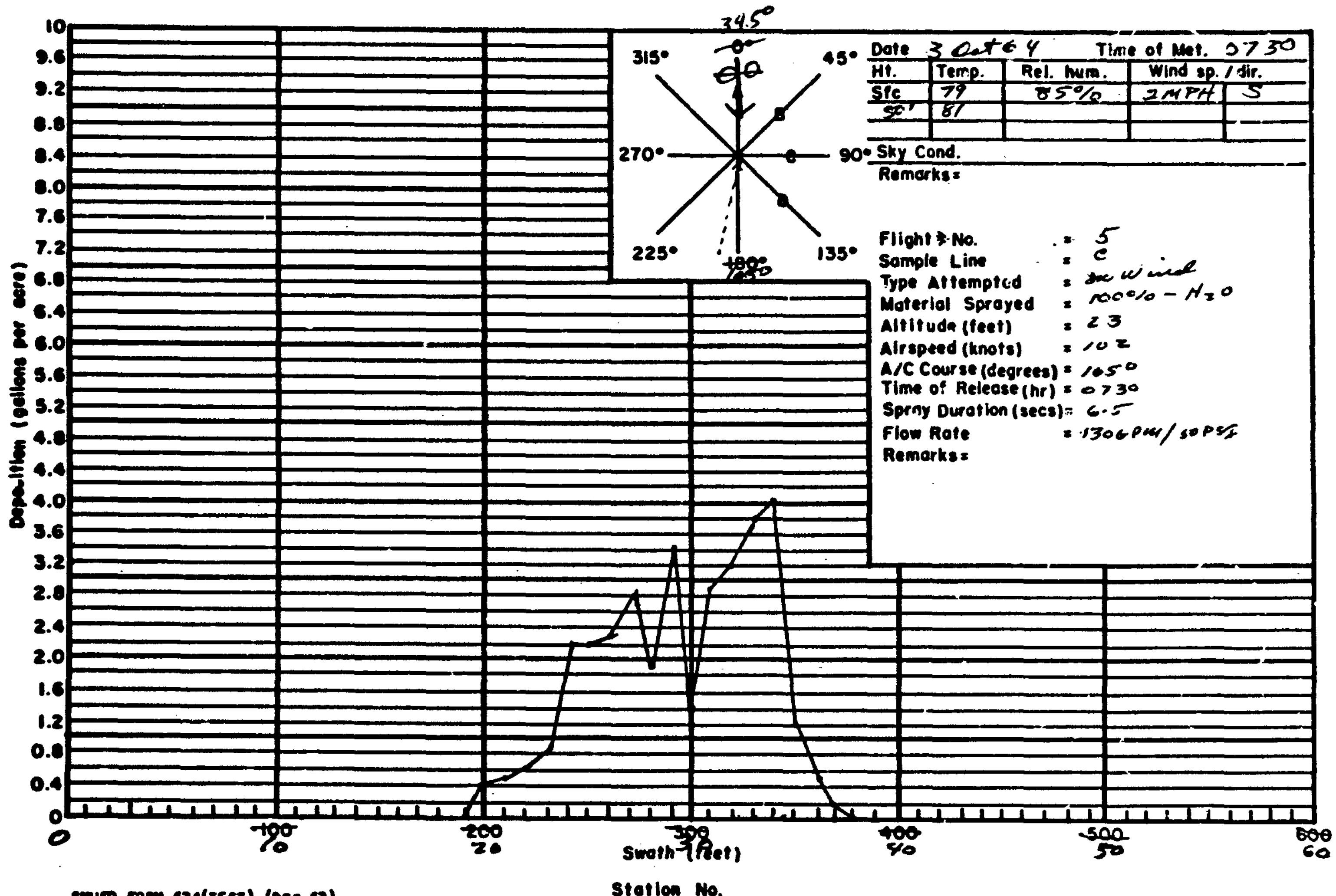
Airspeed 100 Knots
Altitude 30 ft
Swath Width
Aircraft Course 120
Wind Vector 0.0/SE
Spec. 20
Spec. Oper. Kha

St	GPA	St	GPA	St	GPA	St	GPA
1		26	2.30	51		76	
2		27	1.85	52		77	
3		28	2.20	53		78	
4		29	1.75	54		79	
5		30	3.20	55		80	
6		31	2.60	56		81	
7		32	2.20	57		82	
8		33	3.30	58		83	
9		34	3.20	59		84	
10		35	1.50	60		85	
11		36	0.80	61		86	
12		37	0.80	62		87	
13		38	0.42	63		88	
14		39	0.30	64		89	
15		40	0.20	65		90	
16	0.00	41	0.08	66		91	
17	0.08	42	0.08	67		92	
18	0.08	43	0.15	68		93	
19	0.50	44	0.15	69		94	
20	0.55	45	0.00	70		95	
21	0.42	46	0.0	71		96	
22	0.80	47		72		97	
23	1.10	48		73		98	
24	1.25	49		74		99	
25	2.40	50		75		100	

Total Deposit= 25.26

Percent Recovery= $\frac{25.26 \times 2.3}{68} = 85.4\%$

SMUFD FORM 847 (Temp)
(9 April 1963)



SMUFD FORM 634(TEST) (DEC 63)

B. SWATH WIDTH

Swath width was determined most accurately from direct inwind releases under inversion conditions with the aircraft crossing the grid sampling line at right angles. In the initial phases of the test program in which separate wing booms were employed, the deposit patterns were expressed as a bimodal curve. After modification of the boom system to provide under-fuselage nozzles, triangular or trapezoidal deposit patterns were obtained. Spray applications from a height of 35 feet resulted in a swath width of approximately 100 feet.

The graphs of mass deposit (SMUFD Form 634-Dec 63) were used to determine swath width at any desired deposit level.

C. 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.

The following information was required for determination of percentage recovery:

a) Total deposit in gallons per acre on all sampling stations
b) Interval or distance in feet between sampling stations
c) Air speed in statute miles per hour
d) Flow rate in gallons per minute
e) Constant, 0.202, representing the portion of an acre covered in 1 minute at 1 mph for a swath width of 1 ft.

Percentage recovery was calculated by the following equation:

$$\text{Percentage recovery} = \frac{(0.202)\ (\text{Total deposit})\ (\text{Interval})\ (\text{Speed})}{(\text{Flow rate})}$$

For each treatment a summation report was prepared based on all grid flights for a given treatment. This report included calculations of the following:

a) Average percentage recovery of all grid flights
b) Gallons per acre delivered from the plane system
c) Gallons per acre deposited on a 300-ft swath based on delivered volume x average percentage recovery
d) Gallons per acre deposited on a 300-ft swath based on average mass deposit volumes of a 150-ft swath less the average deposit volumes of the swath extremities (tails) outside the 300-ft swath

e) Percentage recovery of the 300-ft swath width
f) Percentage loss outside of the 300-ft swath
g) Total percentage recovery
h) Pounds per acre of acid equivalent or active ingredient.

SUMMATION REPORT

DATE
MATERIAL
TREATMENT NO.
PLOT 1
PLOT 2

Calculations

SUBJECT

1. Average % Recovery

$$\frac{\text{Sum of Total \% Recoveries}}{\text{No. of Recoveries}}$$

2. GPA Delivered from Plane

$$\frac{\text{Flow Rate in GPA}}{\text{23 Acres/Minute}}$$

3. Calculated GPA for 300-ft Swath

GPA from Plane x Average % Recovery

4. GPA Calculated from 300-ft Swath

$$\frac{\text{3(Average Total Deposit of 150-ft Swath) - Sum of Average Two Tails}}{30}$$

5. % Recovery Calculated from 300-ft Swath

$$\frac{\text{GPA of Swath Path}}{\text{Calculated GPA of Plane}}$$

6. % Lost outside 300-ft Swath

$$\frac{\text{Sum of Average Two Tails}}{\text{Sum of Average Two Tails}} + \text{Sum of Average Swath}$$

7. Total Recovery

% Lost outside Swath + Recovery from 300-ft Swath

8. Acid Equivalent Per Acre

GPA x Acid Equiv. = AEQPA

D. MASS MEDIAN DIAMETER OF SPRAY DROPLETS

The droplet characteristics of the chemical mixtures used in the test program were determined by the maximum diameter (D-max.) method developed by Maksymiuk of the U.S. Forest Service Forest Insect Laboratory at Beltsville.* This method provides rapid and fairly accurate estimation of mass median diameter (MMD) from measurements of the largest drops in the complete droplet spectrum. Droplet diameters to the nearest 100 microns were made of the largest droplets impinged on the Kromecote cards used in the grid calibration flights. Diameter of the largest droplet in a series of 10 to 15 observations was used as spot D-max.

The spherical drop D-max. was obtained by dividing the spot D-max. by a calculated spread factor. The spread factor is a constant that relates the final spot size on the Kromecote card with the size of the original droplet:

$$\text{Spherical Drop D-max.} = \frac{\text{Spot D-max.}}{\text{Spread Factor}}$$

$$\text{Spread Factor} = \frac{\text{Final Spot Diameter}}{\text{Spherical Drop Diameter}}$$

The spread factors for the oil-soluble materials ranged from 5.608 to 6.441, and for water-soluble chemicals from 1.70 to 3.00.**,***

Estimated mass median diameters were obtained from spherical drop D-max. using a conversion factor derived empirically by Maksymiuk based on the aircraft speed. The conversion factor varies from 2.2 for slow speeds (80 mph or more) to 2.5 for high-speed delivery systems (150 to 180 mph). The following formulas were used to determine mass median diameter:

$$\text{Estimated MMD} = \frac{\text{Spherical Drop D-max.}}{\text{Conversion Factor}}$$

$$\text{Estimated MMD} = \frac{\text{Spot D-max.}}{\text{Conversion Factor}}$$

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* Brown, J.W.; Whittam, D. July 1962. Modification and calibration of defoliation equipment (C-123 First Modification) (A joint report by personnel of U.S. Department of Agriculture, U.S. Air Force, and U.S. Army Chemical Corps of work performed under OSD/ARPA Order 256, Amendment 4) Crops Division, U.S. Army Biological Laboratories, Fort Detrick, Maryland.

** Wolf, W.R. 1962. Report to Crops Division on spread factor calibration studies of Eglin A.F.B. test agent samples and OCONUS agent samples. Physical Sciences Division, U.S. Army Biological Laboratories, Frederick, Maryland.

*** Wolf, W.R. 1964. Spread factor calibration study of oil-soluble defoliants, fuel oil and water-soluble defoliants on Kromecote cards, (Unpublished Report). Physical Sciences Division, U.S. Army Biological Laboratories, Fort Detrick, Maryland. 154 p.

APPENDIX D

IN-FLIGHT DATA FORM

Treatment No. 92 Date 13 May 1965

Treatment 1:1 Pink - Diesel 2.2 GPA

Rate Volume (Gal/Acre)

Plot Numbers 0(56-60) 5(8-4)

<u>Tank Readings</u> (in gallons)

Initial gal. in tank 120
Initial ground reading 115

Initial in-flight reading 115
After pressure regulation 108

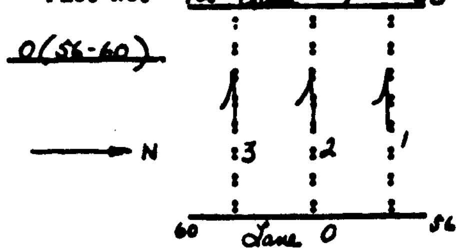
Final in-flight reading 35

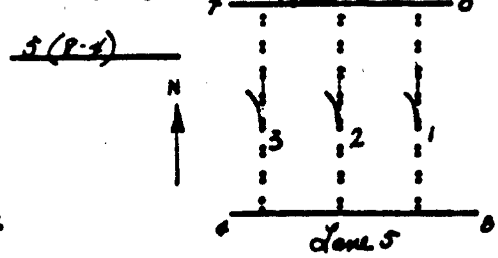
Final ground reading 35

Amount removed from tank 35

<u>Plot Application Diagrams</u>

Plot No. 72 Lane P 68 Plot No. 4 Lane 6 8





<u>Grid and Plot Application Data</u>

	Grid Run	Plot 1	Plot 2	Plot 3	Grid Run	Plot 1	Plot 2	Plot 3	Grid Run
Time	0616	0620	0623	0625	0629	0635	0637	0640	0644
Speed (knots)	100	100	100	100	101	105	102	101	102
PSI	25	25	25	25	27	26	25	25	26
Duration (sec.)	10.1	8.1	8.0	7.6	7.1	8.0	9.1	7.9	7.6
Gauge reading	95	90	73	65	59	50	80	42	35
Delivered volume	13	5	7	8	6	9	10	8	7
Direction of flight	E-W	E-W	E-W	S-N	S-N	N-S	N-S	N-S	S-N

Remarks: Smoke from camp fire shows no ground winds.

APPENDIX E

DESCRIPTION AND OPERATION OF OBSCURIMETER USED IN VERTICAL PHOTOGRAPHY EVALUATION

An obscurimeter or compositing densitometer was designed by Dr. G.B. Truchelut of the U.S. Army Biological Laboratories for quantitative measurements of canopy obscuration on negatives obtained in the vertical photography technique. The instrument is shown in Figure 1.

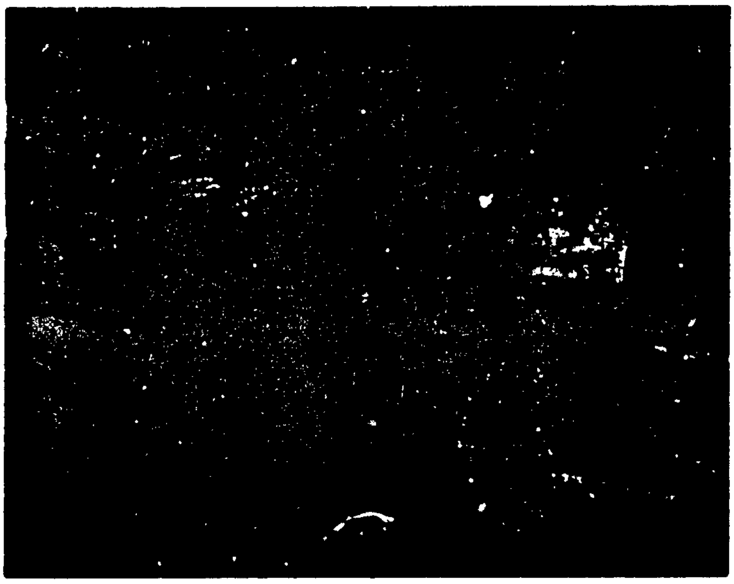


Figure 1. The Obscurimeter as Positioned for Evaluating 35 mm Negatives of Vertical Photographs of the Upper Canopy.

A. BASIC PRINCIPLE

Fundamentally, the instrument consists of a light source with reflector, condensing lenses, and heat-absorbing glass such that a uniform beam of parallel light rays approximately one inch in diameter is produced. This beam is passed through the photographic image of the plot canopy being measured; the transmitted light then impinges on a selenium photocell to produce a current that is proportional to the ratio of light and dark areas on the film. The current is measured by a milliammeter.

B. DESCRIPTION

The light source consists of a 100-watt 115-volt projection lamp wired in series with a cylindrical wire-wound rheostat that can be adjusted to regulate the light output. This adjustment is used in compensating for variations in light absorption of the film base and emulsion due to storage or processing. The light beam is collimated by means of a spherical reflector behind the lamp in conjunction with condenser lenses between the lamp and the film. A glass heat (infrared) absorber is placed between the two halves of the condenser system to protect the film from damage by these wavelengths.

The film carrier or guide consists of a two-piece metal plate containing a carefully machined slot to hold the film strip in correct alignment with the light beam and the photocell, and with a small clearance between emulsion side of the film and the plate so that the image is not scratched or damaged. Near one end of the plate a plastic film support is mounted on the lamp housing. At the other end of the film guide is a sprocket-drive wheel that moves the film the required distance for the examination of successive frames, and this is followed by a second plastic film support.

The light-measuring device, a selenium photocell, is mounted in the film guide plate immediately behind the film. Extraneous light not passing through the desired film area is controlled by means of two diaphram plates each containing a circular aperture of 22-mm diameter, which is equal to the diameter of the circular area to be measured on each photograph.

The photocell is mounted on a sliding panel arrangement so that it can be pulled out of the light path for visual inspection of the film frame being measured.

Final link in the measurement chain is the milliammeter that measures the current output of the photocell. This is calibrated from 0 to 100 in intervals of two. It is read as percentage transmittance.

One additional electrical circuit was installed as a modification. This produces a "bucking" current, or dark current, which permits adjusting the meter to read zero when a zero-transmittance reference frame is placed in position. This circuit consists of a second photocell placed near the light source and through a rheostat connected in reverse to the milliammeter. This circuit is needed because all zero transmittance frames (open sky) cannot be made black enough to provide actual zero transmittance without running into film overexposure troubles. Therefore, the dark current circuit provides a means of zeroing the instrument on the black sky frame, and at the same time compensating for small variations in sky image density from one film strip to another.

A power supply voltage regulator is used in conjunction with the obscurimeter to eliminate variations in light output due to line voltage fluctuations.

C. CALIBRATION

Prior to its use in experimental evaluations, the instrument was calibrated against a film strip made from a series of charts. These charts consisted of segmented circles corresponding to the circular field used in each canopy photograph. The circle areas were divided radially into various ratios of black and white segments in 10% increments from 0% black (all white) to 100% black. In addition, some charts were made with the same area ratios but with different patterns. Following measurements of transmittance of the film strip of the circular charts, a calibration curve was drawn and used in the evaluation of all plot film strips.

D. OPERATION

The procedure in using the instrument to measure obscuration is fairly simple. The film strip is inserted in the film-carrier slot from the left end with the emulsion side toward the operator and moved through far enough for the perforations of the film to engage the film-drive sprockets. The film-drive sprocket wheel is then adjusted so that the first frame to be measured is exactly centered in the aperture, which can be done visually with the photocell moved out of the way.

After adjustment of the drive sprocket, the film is turned to the blank frame and the lamp circuit rheostat is adjusted so that the meter reads 100% transmittance. The film is then moved to the adjacent black-sky frame and the "dark current" is adjusted with potentiometer so that the meter reads zero. The frames containing the canopy silhouettes are read in succession without changing the adjustment settings. The values of transmittance are recorded.

APPENDIX F

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Advanced Research Projects Agency Washington, D.C., 20301

13. ABSTRACT

A test program was conducted in Thailand in 1964 and 1965 to determine the effectiveness of aerial applications of Purple, Orange, and other candidate chemical agents in defoliation of upland jungle vegetation representative of Southeast Asia on duplicate 10-acre plots. Aerial spray treatments were applied at rates of 0.5 to 3.0 gallons per acre on two test sites representing tropical dry evergreen forest and secondary forest and shrub vegetation. Applications were repeated in alternate 2- to 3-month periods to determine minimal effective rates and proper season of application.

Defoliation effectiveness was evaluated by (i) visual estimates of overall vegetation and individual species defoliation, (ii) measurements of changes in canopy obscuration by a vertical photography technique, and (iii) measurements of changes in horizontal visibility of a human-sized target at various ranges.

Data provided by these techniques were used in comparative evaluation of defoliant chemicals in relation to rate, volume, season of application, canopy penetration, and vegetation response.

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Unclassified
Security Classification