Item ID Number:	00070
Author	Demaree, Kenneth D.
Corporate Author	Department of the Army, Plant Sciences Laboratory, Plant Physiology Division, Fort Detrick, Frederick, Maryland
Report/Article Title	Defoliation Tests in 1966 at Base Gagetown, New Brunswick, Canada
Journal/Book Title	
Year	1968
Month/Day	October
Color	☑
Number of Images	29
Description Notes	Project 1B562602A061; This item is a duplicate of item no. 29. Dr. Young placed this report in the category, "Evaluation of Chemicals, How Selected" (Series A, item 29) and in the category, "Military Use of Herbicides (Series B, item 70)

Military

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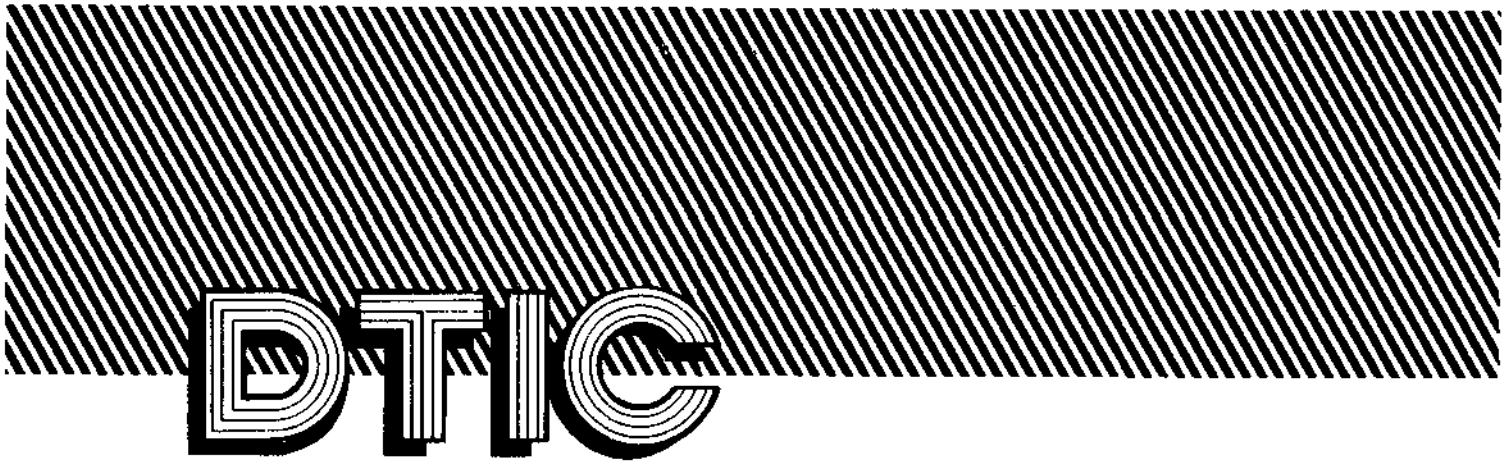

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June 1982

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TECHNICAL MEMORANDUM 141

DEFOLIATION TESTS IN 1966 AT BASE GAGETOWN, NEW BRUNSWICK, CANADA

Kenneth D. Demaree
Richard A. Creager

OCTOBER 1968

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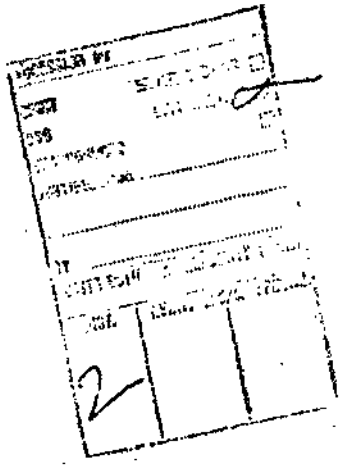

DEPARTMENT OF THE ARMY
Fort Detrick
Frederick, Maryland 21701

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DEFOLIATION TESTS IN 1966 AT BASE GAGETOWN, NEW BRUNSWICK, CANADA

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Plant Physiology Division
PLANT SCIENCES LABORATORY

Project 1B562602A061

October 1968

ACKNOWLEDGMENTS

This work could not have been accomplished without the help of Richard McCrary, U.S. Army Aviation Test Board, who piloted the helicopter; MAJ C.E. Murdoch, Range Officer, who spent long hours in the field with us locating areas and assisting in applications; CPT William Wright, Air Observation Post, who co-piloted the aircraft; the enlisted men of the Royal Canadian Army Service, the Royal Canadian Horse Artillery, and the Air Observation Post.

Our special thanks go to COL C.D. Simpson, Commanding Officer of base Gagetown, for making facilities of Canadian Forces Base Gagetown available.

ABSTRACT

In June 1966, aerial spray tests were conducted at Base Gagetown, New Brunswick, Canada, by personnel of the Biological Sciences Laboratory, Fort Detrick, Maryland, in collaboration with the Canadian Ministry of Defence. Plots in a dense forest of conifers and broadleaf deciduous species were sprayed with herbicides and desiccants by helicopter to determine the effectiveness of nine compounds and their combinations.

Preliminary results of these tests indicated that the phenoxy compounds (ORANGE, PURPLE, and 2,4-D plus 2,4,5-T) appeared very effective on hardwoods, but had little or no effect on conifers; picloram formulations caused moderate brownout on conifers as well as on hardwoods when applied at more than 2 lb./acre. The desiccating agents diquat and cacodylic acid caused rapid brownout of most species but regrowth occurred rapidly.

DIGEST

Aerial spray tests on a heavily forested area were conducted by personnel of the Biological Sciences Laboratory, Fort Detrick, Maryland, in collaboration with the Canadian Ministry of Defence at Base Gagetown, New Brunswick, Canada, in June 1966.

A total of 116 plots, each 200 by 600 feet with a 100-foot buffer strip between plots, were marked off along both sides of a trail through this forested area.

A U.S. Army helicopter equipped with a HIDAL system was used to spray herbicides and desiccants on the plots.

Monthly evaluations of desiccation and defoliation responses were made during the growing season following application; in the year following treatment, plant kill was determined.

Preliminary results of these tests were:

1) ORANGE, PURPLE, and a mixture of 70% 2,4-D + 30% 2,4,5-T as n-butyl esters appeared very effective on hardwoods, but had little or no effect on conifers.

2) Picloram and M-2993 caused moderate brownout on hemlock, fir, pine, and spruce as well as on hardwoods when applied at more than 2 lb./acre.

3) Cacodylic acid and diquat caused rapid brownout on most species when applied at high rates. Regrowth occurred within 2 months.

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I. INTRODUCTION

In 1963, chemical compounds were screened at Fort Ritchie and Fort George G. Meade, Maryland, in wooded areas on individual trees and in small wooded plots to evaluate their effectiveness as defoliants and desiccants.

In 1964, aerial spray tests were conducted on transmission line rights-of-way in Georgia and Tennessee to evaluate effectiveness of several commercially available herbicides. Applications were made by helicopter on plots of approximately 3 acres. An additional series of selected commercial herbicides and several newly synthesized chemicals were applied by ground equipment at Fort George G. Meade, Maryland, in a deciduous hardwood forest.

In 1965, monthly applications were made from May through September at Aberdeen Proving Grounds, Maryland, for the evaluation of defoliation and herbicidal effectiveness of candidate chemical agents on several hardwood species.

The Department of the Army, Fort Detrick, Maryland, has been charged with finding effective chemical agents that will cause rapid defoliation of woody and herbaceous vegetation. To further develop these objectives, large areas similar in density to those of interest in Southeast Asia were needed. In March 1965, the Canadian Ministry of Defence offered Crops Division large areas of densely forested land for experimental tests of defoliant chemicals. This land, located at Canadian Forces Base Gagetown, Oromocto, New Brunswick, was suitable in size and density and was free from hazards and adjacent cropland. The test site selected contained a mixture of conifers and deciduous broadleaf species in a dense undisturbed forest cover that would provide similar vegetation densities to those of temperate and tropical areas, such as Southeast Asia.

The test site was located in the western portion of Base Gagetown between Broad Road and Blissville Road (Fig. 1). The base of operations was located at Blissville Air Strip approximately 2 to 4 air miles from the test site.

The test site was an undisturbed forest consisting of a mixture of conifers and broadleaf deciduous species ranging in height from about 20 to 75 feet. It was approximately 4 miles long by 1,200 feet wide. Terrain in this area varied from swamp to outcroppings of bedrock, with vegetation varying with changes of terrain. At first, wheeled vehicles such as jeeps and 3/4-ton trucks were able to traverse the swampy areas along the trail, but eventually only tracked vehicles could navigate through the mud and mire.

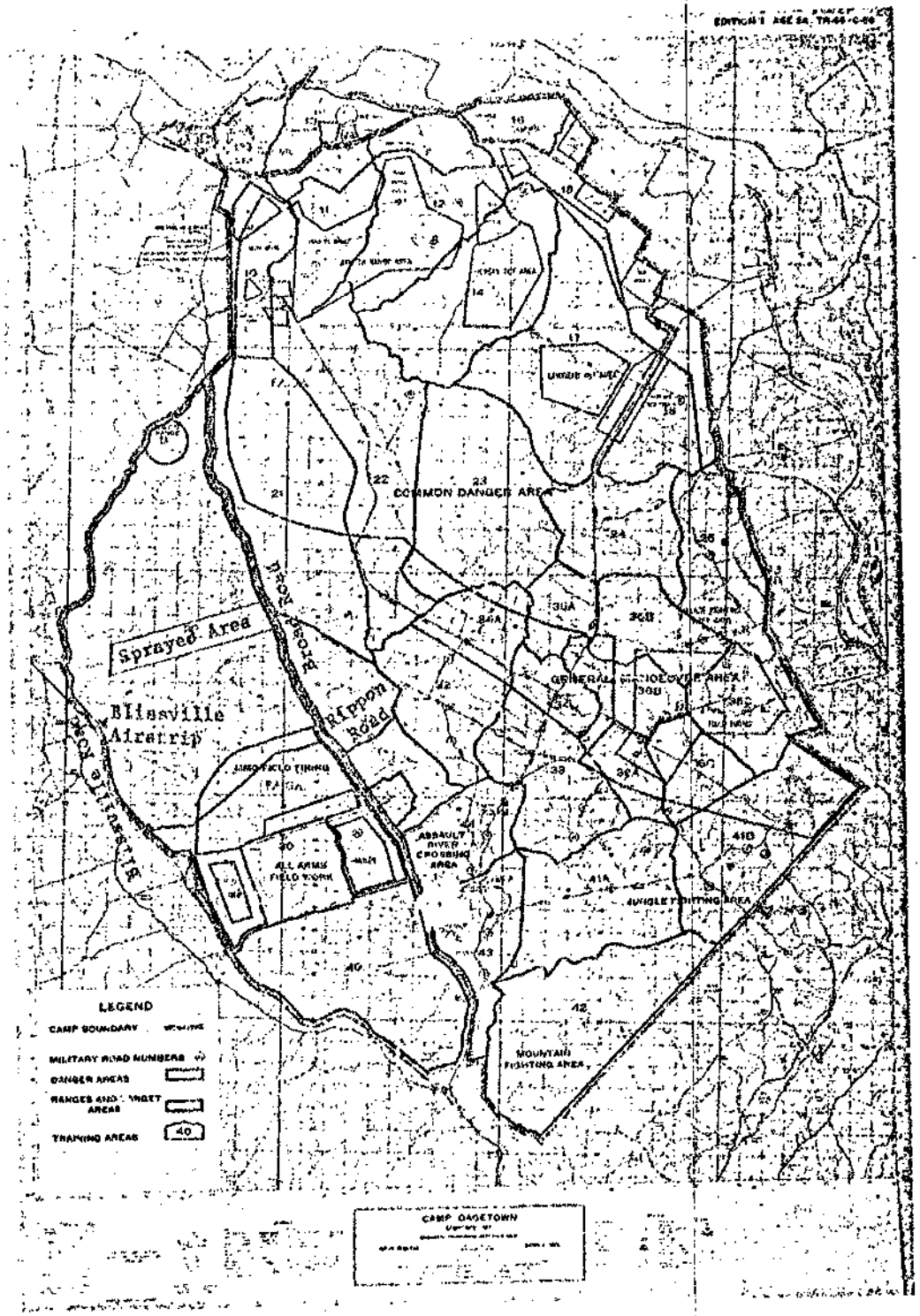

Figure 1. Ranges and Training Areas.

II. MATERIALS AND METHODS

A total of 116 plots, each 200 by 600 feet with a 100-foot buffer strip between plots, were marked off along both sides of an east-west oriented trail through this forested area (Fig. 2). The corners of each plot were delineated by strips of colored surveyor's tape and a corner of each plot was marked with a 6-inch-square, bright orange aluminum plate bearing a numeral 2 inches high.

The predominant species in this area were:

Scientific Name	Common Name
Abies balsamea	balsam fir
Acer pennsylvanicum	striped maple
Acer rubrum	red maple
Alnus incana	speckled alder
Betula papyrifera	paper birch
Betula populifolia	gray birch
Fagus grandifolia	American beech
Picea glauca	white spruce
Pinus resinosa	red pine
Pinus strobus	white pine
Tsuga canadensis	eastern hemlock

Isolated specimens of black ash, poplar, white oak, arborvitae, huckleberry, and silver maple were also present.

A U.S. Army helicopter, loaned to Crops Division by the Army Aviation Detachment, U.S. Army Electronics Command, Fort Monmouth, New Jersey, and piloted by Richard D. McCrary, U.S. Army Test Board, Fort Rucker, Alabama, was used in these tests. The helicopter was equipped with a Helicopter Insecticidal Dispersal Apparatus, Liquid (HIDAL) spraying system (Fig. 3). This system consisted of a 200-gallon fiber glass tank, an electrically driven centrifugal pump, and two booms, each approximately 25 feet long with nozzle outlets spaced every 6 inches along the boom. The booms were fitted with 15 check valves per boom with No. 8010 Teejet nozzle tips. The helicopter was flown at treetop level at 65 knots airspeed during the spray operations.

Plots were flagged for the pilot with telescopic fiber glass poles that extended to a height of 50 feet. A fluorescent orange flag was attached to the tip of the poles. The flagmen stood on the trail halfway between plot markers, and the helicopter flew over the flag. Occasionally, trees hid the flag and the pilot had to request ignition of a smokepot.

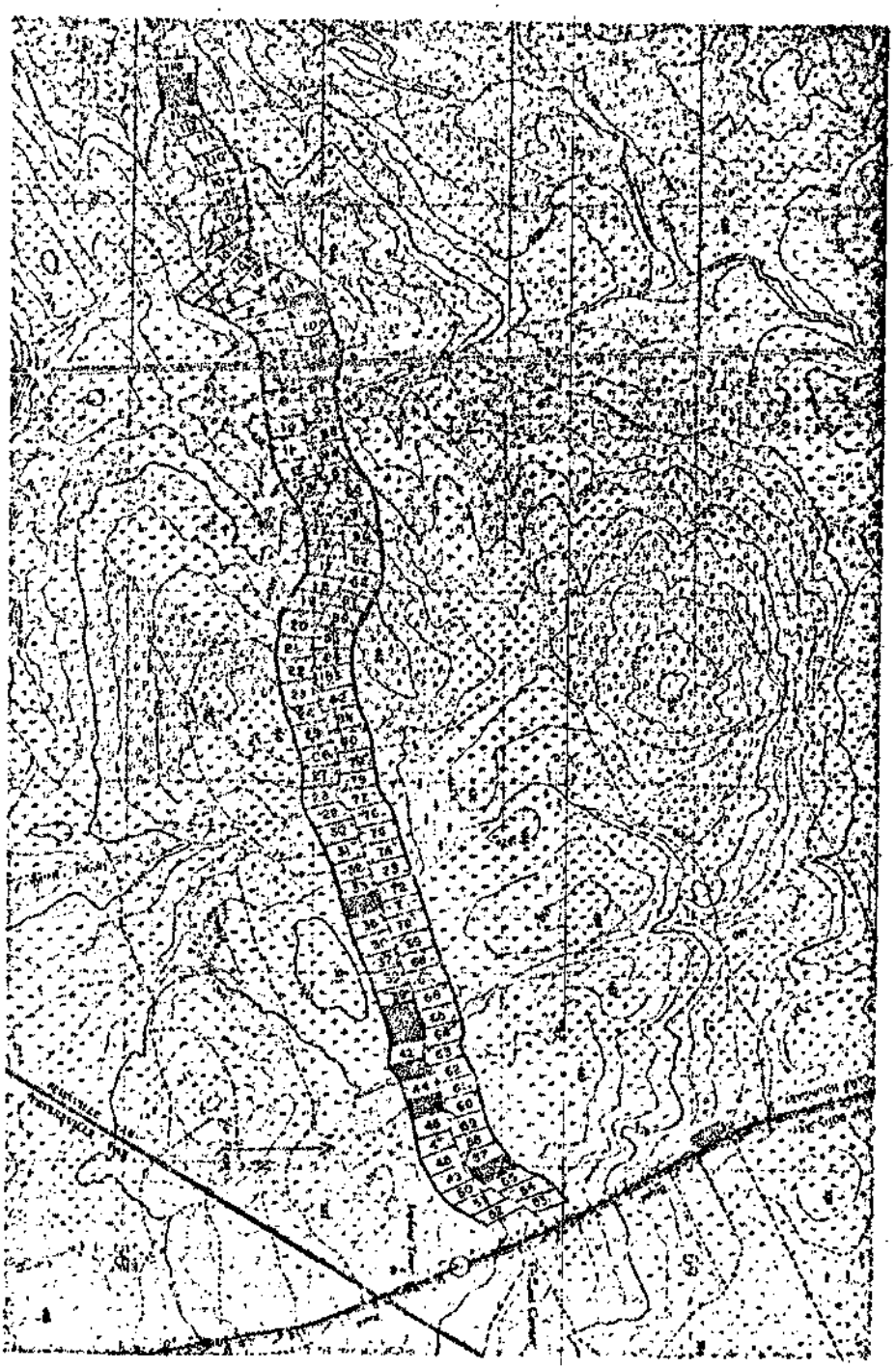

Figure 2. Plot Arrangement. Shaded plots are check plots.

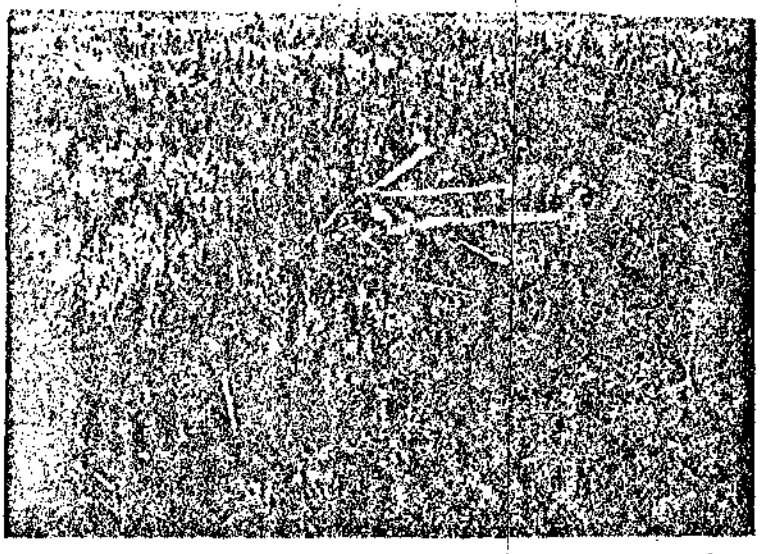

Figure 3. H-19 Helicopter Spraying at Test Site, June 1966.

The compounds were applied at the rates of 1, 2, 3, or 4 gallons per acre on duplicate plots. Because the HIDAL system was calibrated to deliver 1 gallon per acre, the pilot had to fly over the same area two to four times to deliver the higher rates.

Because the trail was very winding, the pilot flew each plot on the same magnetic compass bearing so that the sprayed areas would not overlap. The trail was oriented generally in an east-west direction so that all plots to the north of the trail were sprayed on a compass heading of 360 degrees; those to the south were sprayed on a heading of 180 degrees.

Spraying began on 14 June 1966 when the new leaves were fully expanded and the trees actively growing. Spraying was done during a stationary low pressure atmospheric condition when there was little or no wind so that spraying was continuous from daylight to dark for 3 successive days, thereby completing 107 plots in about 30 hours' actual flying time. The remaining nine plots were left as check plots.

Chemicals used for spraying were, on the whole, commercial compounds of proven effectiveness in eastern United States, but unproven in areas north of Maine. Nine chemicals were used both singly and in various combinations at volume applications of 1 to 4 gallons per acre.

The compounds used in these tests are listed in Table 1.

Chemical treatments in gallons per acre are listed in Table 2.

TABLE 1. CHEMICALS USED IN TEST PROGRAM

Name	Type	Formulation
ORANGE 50-50 mixture n-butyl esters of 2,4-D and 2,4,5-T	Herbicide	10.7 lb./gal
PURPLE 50% n-butyl ester 2,4-D, 30% n-butyl ester 2,4,5-T, and 20% isobutyl ester 2,4,5-T	Herbicide	10.7 lb./gal
70% 2,4-D + 30% 2,4,5-T 70-30 mixture of n-butyl esters 2,4-D and 2,4,5-T	Herbicide	10.7 lb./gal in combined form
TORDON 22K 4-amino-3,5,6-trichloro-picolinic acid (potassium salt of picloram)	Herbicide	2 lb./gal picloram
TORDON 101 mixture of triisopropanolamine salt of picloram and 2,4-D	Herbicide	0.54 lb./gal picloram + 2.0 lb./gal 2,4-D
M-2993 1:4 mixture of isooctyl ester of picloram + propylene glycol butyl ether ester of 2,4,5-T	Herbicide	1 lb./gal picloram 4 lb./gal 2,4,5-T
DIQUAT 1,1'-ethylene-2,2'-dipyridinium dibromide	Fast acting desiccant	2 lb./gal of diquat cation
PHYTAR 160 Sodium cacodylate (dimethylarsinic acid) + surfactant	Fast acting desiccant	3.1 lb./gal active ingredient;5% surfactant
PHYTAR 560 Sodium cacodylate (dimethylarsinic acid) + surfactant	Fast acting desiccant	2.48 lb./gal active ingredient;1 qt/gal surfactant

TABLE 2. CHEMICAL TREATMENTS APPLIED IN AERIAL SPRAY TESTS

Chemical	Volume, gal/acre
ORANGE	1, 2, 3
ORANGE + Diesel (1:1)	1, 2, 3
ORANGE + Diesel (1:2)	3
PURPLE	1, 2, 3
PURPLE + Diesel (1:1)	1, 2, 3
PURPLE + Diesel (1:2)	3
70% 2,4-D + 30% 2,4,5-T	1, 2, 3
70% 2,4-D + 30% 2,4,5-T + Diesel (1:1)	1, 2, 3
Tordon 22K + Water (1:1)	1, 2, 3
Tordon 22K + Diquat + Water	1, 2
Tordon 22K + Phytar 160 (1:3)	1
Tordon 101 + Diquat (1:1)	1, 2
Tordon 101 + Phytar 160 (1:1)	1, 2
M-2993 + Diesel (1:1)	1, 2
M-2993 + Diesel (1:2)	2
Diquat	1, 2, 3
Diquat + Water (1:1)	2, 3, 4
Diquat + 10% DMSO[a]	2, 3, 4
Diquat + Tordon 101 (1:1)	1, 2
Diquat + Tordon 22K (1:1)	1, 2
Phytar 560 + Water (1:1)	1, 2, 3
Phytar 560 + Water (1:2)	3
Phytar 160	1, 2, 3, 4
Phytar 160 + Water (1:1)	1, 2, 3
Phytar 160 + Water (1:2)	1
Phytar 160 + Tordon 22K (1:1)	1, 2
Phytar 160 + Tordon 22K (3:1)	1

a. DMSO = dimethyl sulfoxide.

The rating system used for evaluating the plots was based on a score of 0 to 3; 0 = no effect, 1 = slight, 2 = moderate, 3 = extreme. Two categories, desiccation and defoliation, were recorded. No attempt was made to score death of plant species in 1966 because this is usually done the year after spraying.

Plots were evaluated at monthly intervals from time of application to the end of September 1966. Overall injury was evaluated while flying over the area in a light aircraft (Fig. 4 to 6). Radio contact was maintained with a ground crew for the plot identification. Certain plots, those that were sprayed at 3 and 4 gallons per acre and with high concentration of material, were evaluated by walking into the sprayed area and recording effects of various species (Fig. 7 and 8). Color photographs were taken from the air, from the trail, and from inside the plot.

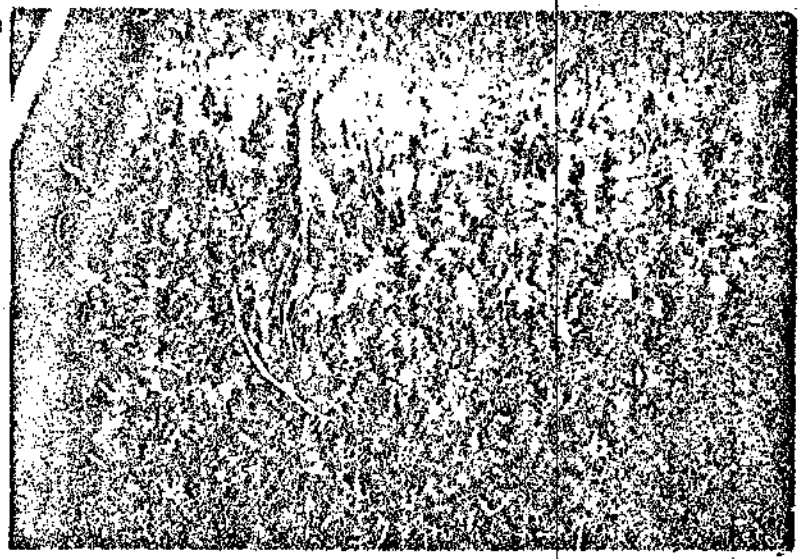

Figure 4. Aerial View of Treatment Plots Showing Untreated Buffer Zone at Front, August 1966.

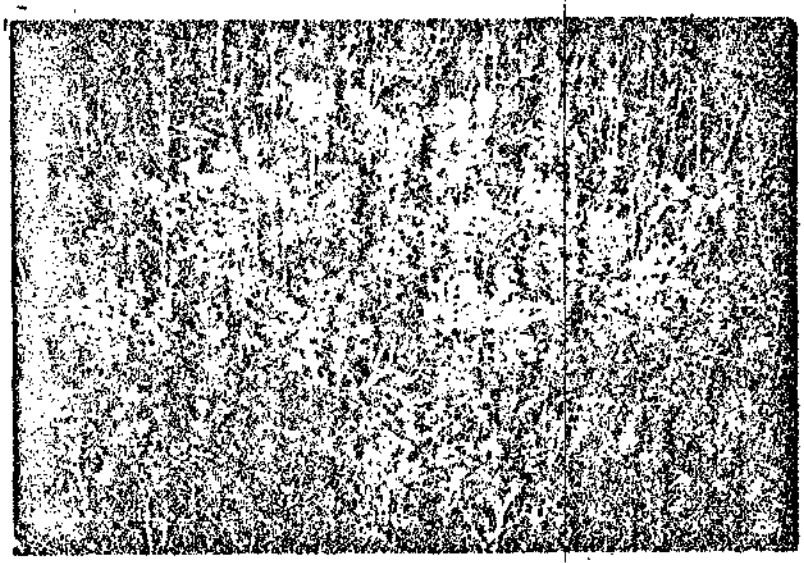

Figure 5. Aerial View Showing Effects of ORANGE Sprayed June 1966; Photographed August 1966.

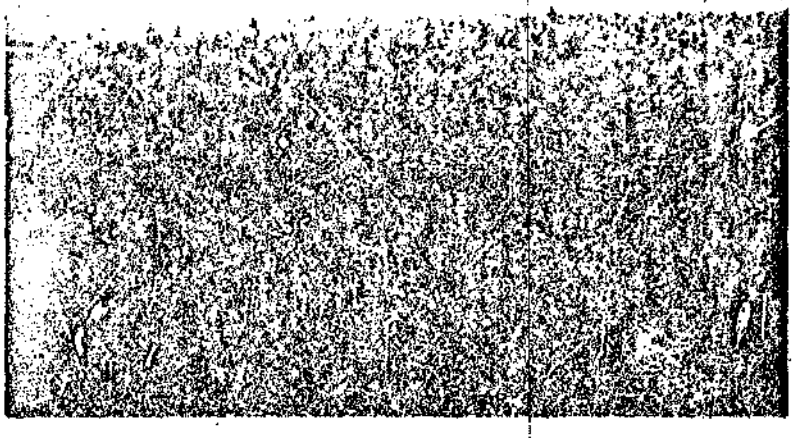

Figure 6. Aerial View Showing Treatment Plots Sprayed June 1966; Photographed August 1966.

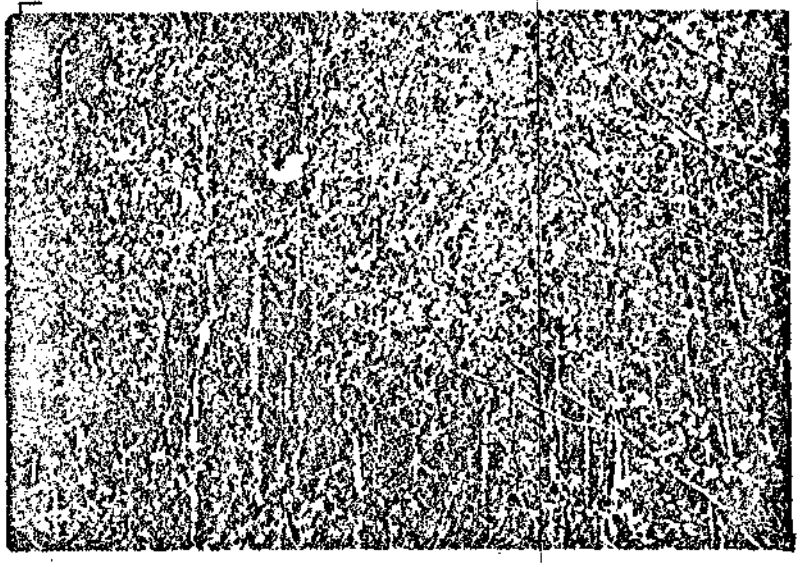

Figure 7. Close-Up Showing Effect of Diquat after 3 Days.

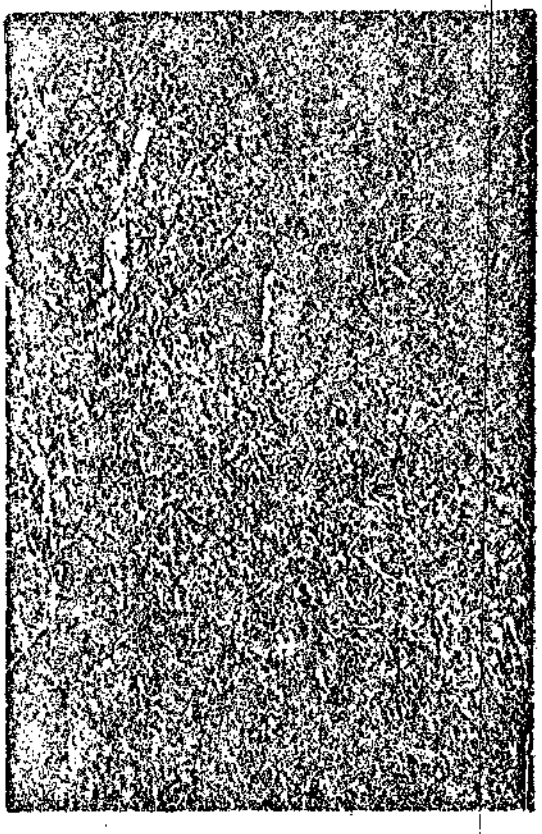

Figure 8. Effect of Tordon 22K on Beech Sprayed at 1.5 Gal/Acre Picloram; Sprayed June 1966, Photographed August 1966.

III. RESULTS.

Data on defoliation responses of hardwood species at 3 months after application are presented in Table 3. Desiccation responses of conifers at 2 and 3 months after treatment are outlined in Table 4.

ORANGE and PURPLE gave effective defoliation of broadleaf species in applications of 10.1 to 32.1 pounds active ingredient per acre (equivalent 1:1 mixture with diesel fuel or 3 gal/acre pure chemical); only slight desiccation and no defoliation were noted on conifers at the end of 3 months.

A modified ORANGE consisting of 70% 2,4-D and 30% 2,4,5-T gave a moderate to extreme defoliation of broadleaf species, but some regrowth of red maple and striped maple occurred when applied at the rate of 32.1 lb./acre. Conifers showed only slight or negligible response except for arborvitae. This minor species exhibited extreme desiccation combined with moderate defoliation.

M-2993, a formulation containing 1 lb./gal of isooctyl ester of picloram and 4 lb./gal of 2,4,5-T as propylene glycol butyl ether ester, gave moderate to extreme defoliation of broadleaf species and slight to moderate desiccation of conifers at 3.32 lb./acre total acid equivalent.

Sodium cacodylate formulated as Phytar 560 and Phytar 160 gave variable defoliation responses on broadleaf hardwoods at rates of 1.6 to 13.0 lb./acre. Phytar 560 containing 25% surfactant in the formulated product gave more effective defoliation than Phytar 160 lacking the surfactant. Conifers showed only slight desiccant effect at 2 to 3 months after treatment.

Diquat applied at 4.0 to 6.0 lb./acre gave extreme and rapid defoliation of broadleaf deciduous trees but regrowth was noted 2 to 3 months after application. Red pine showed extreme browning or desiccation with moderate defoliation in applications at 6.0 lb./acre. Spruce, fir, and hemlock showed only slight desiccation at 3 months.

Tordon 22K gave extreme defoliation on birch, beech, and red maple at 3.0 lb./acre. Spruce showed extreme desiccation, but fir had only slight desiccant injury.

A mixture of Tordon 22K and diquat (1.2 + 1.2 lb./acre) was moderately effective in defoliation of hardwoods but gave moderate to extreme desiccation of fir, pine, spruce, and arborvitae, with extreme defoliation of arborvitae.

A mixture of Phytar 160 and Tordon 22K (2.45 + 0.5 lb./acre) gave only moderate but variable defoliation of hardwoods and poor desiccation of conifers.

TABLE 3. DEFOLIATION RESPONSES OF HARDWOOD SPECIES AT 3 MONTHS AFTER APPLICATION

Chemical	Rate, lb./acre	Species Response[a]					
		Birch	Red Maple	Beech	Striped Maple	Alder	Ash
ORANGE	32.1	3	3	3	-	-	3R
	10.7	-	3R	-	3R	3	-
PURPLE	32.1	2	3	3	3	3	-
	12.9	3	3	3	3	3	-
	10.7	3	3	1-3	2-3	3	-
70% 2,4-D + 30% 2,4,5-T	32.7	2	3R	3R	3R	2	-
	8.6	-	0	3	0	2R	-
Tordon 22K	3.0	3	3	3	-	-	-
Tordon 22K + Diquat	1.2 + 1.2	1[b]	3	-	-	2	-
Tordon 101 + Diquat	(0.27 + 1.0) + 1.6	3R	2	2[b]	-	3[b]	-
M-2993	5.0	2	3	2	2	3	-
Diquat	6.0	-	3R	-	3R	-	-
	4.0	3R	3R	-	-	3R	-
Diquat + 10% DMSO[c]	6.4 + 1.6	-	-	-	3R	-	-
Phytar 560	3.72	3[b]	2-3[b]	-	-	-	3[b]
Phytar 160	13.0	1[b]	1[b]	-	3[b]	-	-
	4.9	2	0	2	0	-	-
	1.6	-	2	0	0	3	2
Phytar 160 + Tordon 22K	2.45 + 0.5	1[b]	0-2[b]	-	0-2[b]	3	2[b]

a. 0 = no effect, 1 = slight, 2 = moderate, 3 = extreme, R = regrowth, - = no data.
b. Response at 2 months.
c. DMSO = dimethyl sulfoxide.

TABLE 4. DESICCATION RESPONSES OF CONIFERS AT 2 AND 3 MONTHS AFTER APPLICATION

Chemical	Rate, lb./acre	Species Response[a]				
		Red Pine	Spruce	Fir	Hemlock	Arborvitae
ORANGE	32.1	-	-	1	-	-
	8.6	-	-	1	1	-
PURPLE	25.6	-	1	1	-	-
	12.9	1	1	1	-	-
	8.6	2	0	-	-	-
70% 2,4-D + 30% 2,4,5-T	25.8	-	-	1	-	3[b]
	8.6	-	0	1	0	-
Tordon 22K	3.0	-	3	1	-	-
Tordon 22K + Diquat	1.2 + 1.2	-	2-3[b]	2	-	3[b]
Tordon 101 + Diquat	(0.27 + 1.0) + 1.6	-	1	-	-	-
M-2993	5.0	2	0-1	1-2	2	-
Diquat	6.0	3[b]	1	1	1	-
Diquat + 10% DMSO[c]	6.4 + 1.6	3	-	-	-	-
Phytar 560	3.72	-	1	-	3	-
Phytar 160	13.0	-	1	-	-	-
	4.9	-	0	1	-	-
	1.6	-	1	1	1	-
Phytar 160 + Tordon 22K	2.45 + 0.5	-	0	1	-	-

a. 0 = no effect, 1 = slight, 2 = moderate, 3 = extreme, - = no data.
b. Extreme desiccation accompanied by moderate defoliation.
c. DMSO = dimethyl sulfoxide.

A mixture of Tordon 101 and diquat gave moderate to extreme defoliation of broadleaf hardwoods but little or no effect on spruce. Data were not available for other conifers.

Table 5 presents data on the death of hardwood species at 14 months after application. Treatments causing death of conifer species are included in Table 6.

Plots sprayed with ORANGE, PURPLE, and a mixture of 70% 2,4-D and 30% 2,4,5-T ranged from 65% to 90% kill on all broadleaf hardwoods. No damage of conifers was apparent in 1967. In nearly all cases, maple was not completely killed and new growth was apparent.

Tordon 22K and Tordon 101 produced some kill on spruce, fir, and pine as well as kill on most of the broadleaf deciduous trees. M-2993 killed beech, aspen, and birch, but maple was regrowing. There was no damage on conifers when sprayed with M-2993.

It was surprising to note that death occurred on some species when sprayed at 4 gal/acre of diquat. Birch in those plots was completely killed and beech was 90% killed. Conifers were not showing any damage from diquat when evaluated in 1967.

Phytar 160 and Phytar 560 showed about equal results. Deciduous broadleaf species were approximately 30% killed, but regrowth was occurring on all species. Conifers apparently were not injured.

TABLE 5. DEATH OF HARDWOODS AT 14 MONTHS AFTER APPLICATION

Chemical	Rate, lb./acre	Species Response[a]				
		Birch	Red Maple	Beech	Striped Maple	Alder
ORANGE	32.1	4	4,2	4	-	4
	21.4	3	-	4	-	4
	15.7	-	-	4	-	4
	10.5	1	1	2	-	3
PURPLE	32.1	4	3,1	3,1	-	4
	21.4	4	3,1	3,1	-	4
	15.7	4	2,2	3	-	3
	10.5	4	2,2	-	3,1	4
70% 2,4-D + 30% 2,4,5-T	32.1	2	2,2	4	2,2	2,2
	10.5	-	2	4	-	-
Tordon 22K	3.0	3,1	3,1	3,1	-	-
Tordon 22K + Diquat	1.2 + 1.2	0,4	0,4	0,4	0,4	0,4
Tordon 101 + Diquat	(0.27 + 1.0) + 1.6	0,4	0,4	0,4	0,4	0,4
M-2993	3.2	4	1,3	4	-	-
Diquat	6.0	0,4	0,4	0,4	0,4	0,4
	4.0	4	-	3,1	-	-
Phytar 560	3.72	4	2,2	-	-	4
Phytar 160	13.0	0,4	0,4	0,4	0,4	0,4
	4.9	0,4	0,4	0,4	0,4	0,4
	1.6	1,3	1,3	-	-	2,2

a. First number of a pair indicates: 1 = up to 20% kill; 2 = 21 to 50% kill; 3 = 51 to 75% kill; 4 = 76 to 100% kill. Second number of a pair, when present, indicates: 1 = up to 20% regrowth; 2 = 21 to 50% regrowth; 3 = 51 to 75% regrowth; 4 = 76 to 100% regrowth.
- = no data.

TABLE 6. DEATH OF CONIFEROUS SPECIES 14 MONTHS AFTER APPLICATION

Chemical	Rate, lb./acre	Species Response[a]			
		Red Pine	Spruce	Fir	Hemlock
Tordon 22K	3.0	2	4	2	-
	1.0	-	3	-	-
Phytar 160 + Tordon 101	2.4 + (0.27 + 1.0)	-	2	-	-

a. 1 = up to 20% kill; 2 = 21 to 50% kill; 3 = 51 to 75% kill; 4 = 76 to 100% kill; - = no data.

IV. DISCUSSION

The phenoxyacetic acids and derivatives generally are effective defoliants and herbicides for use on broadleaf, deciduous species. These herbicides usually cause very little permanent damage on conifers. The needle tips of conifers will brown but no defoliation or death occur.

Diquat and dimethylarsinic acids are very rapid desiccants, causing the leaves of all species to shrivel and turn brown. Terminal and lateral buds are not killed and the plant may refoliate in 6 to 9 weeks after spraying.

Picloram is usually considered the better herbicide for conifers, but unless it is applied at a minimum rate of 3 lb./acre active ingredient there is very little effect on fir, spruce, or hemlock. Picloram is a very effective defoliant and herbicide on broadleaf species, such as birch, beech, and red maple, but other broadleaf species are very resistant to it.

On the basis of defoliation and death responses to the four groups of herbicides and desiccants tested, the species may be classified in the following order of susceptibility:

Susceptible	Resistant
alder	arborvitae
beech	pine
birch	hemlock
red maple	spruce
striped maple	fir
ash	

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Department of the Army
Fort Detrick, Frederick, Maryland 21701

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

DEFOLIATION TESTS IN 1966 AT BASE GAGETOWN, NEW BRUNSWICK, CANADA

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

Kenneth D. Demaree
Richard A. Creager

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
October 1968	25	none

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 1B562602A061	Technical Memorandum 141
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Department of the Army Fort Detrick, Frederick, Maryland 21701

13. ABSTRACT

In June 1966, aerial spray tests were conducted at Base Gagetown, New Brunswick, Canada, by personnel of the Biological Sciences Laboratory, Fort Detrick, Maryland, in collaboration with the Canadian Ministry of Defence. Plots in a dense forest of conifers and broadleaf deciduous species were sprayed with herbicides and desiccants by helicopter to determine the effectiveness of nine compounds and their combinations.

Preliminary results of these tests indicated that the phenoxy compounds (ORANGE, PURPLE, and 2,4-D plus 2,4,5-T) appeared very effective on hardwoods, but had little or no effect on conifers; picloram formulations caused moderate brownout on conifers as well as on hardwoods when applied at more than 2 lb./acre. The desiccating agents diquat and cacodylic acid caused rapid brownout of most species but regrowth occurred rapidly.

14. Key Words

Defoliation
Canada
Herbicides
Desiccation
Helicopter spraying

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☆U.S. Government Printing Office: 1982—381-308/1357