2.01 (90% confidence limits, 1.22-3.15) was reported for all cancers combined.

Conclusions

In this study of professional applicators of pesticide in New Zealand, we have documented substantial exposure to TCDD from use of 2,4,5-T over many years. Our finding that serum levels of TCDD increase only after several years of 2,4,5-T use suggests that exposure to TCDD was probably negligible in the Swedish studies reporting increased risks of soft-tissue sarcoma and malignant lymphomas with short duration of phenoxyherbicide exposures. To date, only one study (*38*) involving substantial exposures to TCDD has revealed an increased risk of soft-tissue sarcoma.

This lack of evidence does not mean that TCDD does not cause cancer in humans. It may mean, rather, that, except for the NIOSH cohort study, the numbers of persons with substantial occupational exposures have been too small to reveal any effects. We cannot determine whether TCDD exposure from prolonged use of 2,4,5-T poses significant health risks, but we can conclude that previous reports in other countries of increased cancer risks from brief exposure to phenoxyherbicides are probably not attributable to the TCDD that contaminates 2,4,5-T.

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Korea DMZ Vets & Agent Orange

Selected ground combat units of the 2nd and 7th Infantry divisions during 1968-69 are OK'd for presumptive compensation.

by Ted Sypko

Significant information regarding Agent Orange use along Korea's DMZ is now available. The Pentagon has confirmed that Agent Orange was used from April 1968 through July 1969 to defoliate the fields of fire between the front line defensive positions and the south barrier fence.

The size of the treated area was a strip of land 151 miles long and up to 350 yards wide, from the fence to north of the civilian control line. There is no indication that herbicides were sprayed inside the DMZ itself.

The defoliants were applied by South Korean troops by hand-spraying and by hand-distribution of pelletized herbicides. Although restrictions were put in place to limit the potential for spray drift, run-off and damage to food crops, records indicate the effects were sometimes observed as far as 200 meters down wind.

The Defense Department has provided a list of units deployed on four-month rotations up to the DMZ. Presumption for individuals who served in those units during the applicable timeframe has been granted.

For all other claims of herbicide exposure, veterans are advised to contact their VFW Department service officer or call toll-free *1-800-VFW-1899*. The information provided by DoD determines whether exposure can be established. Since March 2003, C&P Service has received approximately 150 such inquiries from Korea DMZ veterans.

On Nov. 22, 2003, Congress passed the *Veterans Benefits Act of 2003*. Sec. 12: Extension of spina bifida benefits for children of Vietnam-Era veterans states: "The parent of the child must have performed active military, naval or air service beginning Sept. 1, 1967, and ending Aug. 31, 1971, in the Republic of Korea in the area between the south line of the Demilitarized Zone and a line five miles south of the Civilian Control Line established with respect to the DMZ. The child would be eligible only if the individual was conceived after the parent performed such service."

For those who will benefit from compensation, these are landmark actions.

"VFW is to be commended for doggedly pursuing this issue for so many years," said C. David Benbow, a Korea DMZ veteran of 1968-69 and activist. "Through its magazine and National Veterans Service, the organization has clearly taken the lead in making presumptive compensation for Korea DMZ vets a priority. VFW should be proud of its educational and lobbying efforts."

For more information about Agent Orange, contact VA's Gulf War/Agent Orange Helpline at *1-800-749-8387* or visit *www.va.gov/agentorange*.

TED SYPKO, *VFW service officer, is retiring in April 2004 after 25 years at VFW.*

Who and What Is Eligible

Mandatory Requirements

- Service in country between April 1968 and July 1969.
- Assignment to a specified unit in Korea between April 1968 and July 1969.
- Medical evidence of presumptive condition under *38 C.F.R. 3.309*.

Military Units Eligible (April 1968 to July 1969)

Elements of four combat brigades of the 2nd Infantry Division:

72nd Armor
 1st and 2nd battalions
7th Cavalry: 4th Battalion
9th Infantry
 1st and 2nd battalions
23rd Infantry
 1st, 2nd and 3rd battalions
38th Infantry
 1st and 2nd battalions

3rd Brigade, 7th Infantry Division:

73rd Armor: 1st Battalion
10th Cavalry: 2nd Battalion
17th Infantry
 1st and 2nd battalions
32nd Infantry: 3rd Battalion

Herbicide-Associated Health Conditions Presumptively Recognized

- Chloracne (must occur within one year of exposure to Agent Orange).
- Non-Hodgkin's lymphoma.
- Soft tissue sarcoma (other than osteosarcoma, chondrosarcoma, Kaposi's sarcoma or mesothelioma).
- Hodgkin's disease.
- Porphyria cutanea tarda (must occur within one year of exposure).
- Multiple myeloma.
- Respiratory cancers, including cancers of the lung, larynx, trachea and bronchus.
- Prostate cancer.
- Acute and subacute transient peripheral neuropathy (must occur within one year of exposure and resolve within two years of date of onset).
- Type 2 diabetes.
- Chronic lymphocytic leukemia.
- Spina bifida (except spina bifida occulta) is a condition recognized in children of some Korea DMZ vets.

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[redacted] Below is "Table 1 – Consumption trends of herbicides by group in Korea," which includes figures for phenoxy herbicide consumption in Korea from 1955-1975. The referenced figures are based on calculations from the "Yearbook of Agriculture and Forestry Statistics (1960-1976), Korea." (We are attempting to obtain this Yearbook.) Also, below is "Table 2 – Annual consumption pattern of herbicides in Korea (average for 1974-75 as active ingredients)," which contains figures for 2,4-D and pentachlorophenol.

Table 1. Consumption trends of herbicides by group in Korea*
(Unit : active ingredient in metric tons/year)

Period \ Group	Phenoxy	Acidamide	Carbamate	Triazin	Others	Total
1955	0.7	—	—	—	—	0.7
1956-60	9.9	—	—	—	—	9.9
1961-65	11.7	0.3	—	—	—	12.0
1966	103.1	0.6	—	0.4	—	104.1
1967	187.1	7.1	—	0.4	—	194.6
1968	253.6	16.6	2.5	3.5	0.2	276.4
1969	346.5	17.3	19.0	1.3	—	384.1
1970	928.7	32.9	25.7	4.1	1.2	992.6
1971	924.8	157.5	26.8	42.2	11.7	1,163.0
1972	553.7	287.1	64.9	38.9	8.5	953.1
1973	455.6	319.3	46.9	15.9	11.3	849.0
1974	824.4	602.9	72.8	16.8	18.3	1,535.2
1975	837.4	1,008.2	65.0	11.9	39.0	1,961.5

*Calculated from Yearbook of Agriculture and Forestry Statistics (1960-1976), Korea

Table 2. Annual consumption pattern of herbicides in Korea
(average for 1974-75 as active ingredients)

Group	Commodity	Total usage (ton)	Distribution (%)
Phenoxy	NIP (nitrofen, TOK)	592.4	33.9
	PCP (pentachlorophenol)	123.6	7.1
	CNP (MO)	82.9	4.7
	2,4-D	21.1	1.2
	MCP	11.1	0.6
Acid amide	Machete (butachlor)	750.8	42.9
	Lasso (alachlor)	32.0	1.8
	DCPA (propanil, stam F-34)	22.8	1.3
Carbamate	Saturn (benthiocarb)	56.7	3.2
	MCC (swep)	12.3	0.7
Triazin	Triazin	12.9	0.7
	CAT (simazine)	1.5	0.1
Others	Paraquat (gramoxone)	27.0	1.5
	Linuron	0.9	0.1
	Devrinol	0.8	0.1
Total		1,748.8	100.0

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TECHNICAL MEMORANDUM 212

THE LATERAL AND VERTICAL MOVEMENT OF FOUR HERBICIDES APPLIED TO A GRASSLAND SOIL

Environmental Fate of 2,4-D & 2,4,5-T

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OCTOBER 1970

DEPARTMENT OF THE ARMY
Fort Detrick
Frederick, Maryland

49863

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DEPARTMENT OF THE ARMY
Fort Detrick
Frederick, Maryland 21701

TECHNICAL MEMORANDUM 212

THE LATERAL AND VERTICAL MOVEMENT OF FOUR HERBICIDES APPLIED TO A GRASSLAND SOIL

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Plant Physiology Division
PLANT SCIENCES LABORATORIES

Project 1B562602AD04 October 1970

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ABSTRACT

Bioassay techniques were used to evaluate the lateral and vertical movements of herbicides ORANGE, WHITE, picloram, and bromacil following application to grassland vegetation on a gravelly loam soil. Picloram and bromacil exhibited vertical and lateral mobility; residual amounts of each herbicide were recovered 1 year after application 50 feet downslope from heavy-rate treatments. Trace amounts of ORANGE were found in the surface soil at 1 year, but WHITE had completely dissipated in this period.

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CONTENTS

TABLES

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I. INTRODUCTION*

The movement and persistence of herbicides in soils has been well documented in the literature[1-5] but few studies have been made of lateral displacement of applied herbicides.[6] Leaching studies of soils conducted under laboratory conditions provide valuable information on herbicide mobility but do not adequately describe behavior in field soils. The vertical movement of herbicides applied at the high rates used for soil sterilization and complete vegetation control has also received little attention, as most field studies utilize the lower application rates employed for selective weed control.

The present study was designed to measure the vertical and lateral displacement of four herbicides used in defoliation and vegetation control: ORANGE, WHITE, bromacil, and picloram. Bioassay techniques were employed to assess the mobility and persistence of the four herbicides applied to grassland vegetation on various slopes. Limited observations were also made of the lateral movement of Tandex on the basis of vegetation response only, as we lacked a suitable method for bioassay of herbicide residues.

II. LITERATURE REVIEW

The behavior in soils of the 2,4-D and 2,4,5-T components of ORANGE has been evaluated in several field studies. Early work at Fort Detrick[1,7,8] showed that 2,4-D disappeared from soils more rapidly than 2,4,5-T, presumably because of the greater rate of microbial decomposition of 2,4-D. Whiteside and Alexander[9] found no evidence of microbial decomposition of 2,4,5-T in soil inoculated with microflora that readily decomposed 2,4-D at herbicide levels used in selective weed control. Field studies on a cultivated fallow soil by Barnett et al.[6] showed that the water-insoluble ester forms of 2,4-D were more susceptible to surface washoff and lateral movement downslope than the water-soluble amine formulations.

The persistence of picloram and its low rate of biodegradation in soils are attested in several field studies.[2-4,10] Picloram is known to be relatively mobile vertically in the soil but few reports have been made on its lateral displacement. Bioassay studies by Goring, Youngson, and Hamaker[3] indicate that the half-life of picloram in soils varies considerably; losses range from 58 to 96% at the end of 1 year. Field studies of heavy rates (3.9 and 27 lb./acre) of picloram applied to Puerto Rican soils as reported by Tschirley[10] showed residues detectable by bioassay techniques at the end of 1 year.

* This report should not be used as a literature citation in material to be published in the open literature.

III. METHODS

The chemical composition and formulation of the herbicides tested are shown in Table 1.

TABLE 1. CHEMICAL COMPOSITION AND FORMULATION OF HERBICIDES USED

Chemical	Composition	Formulation
ORANGE	50:50 (v/v) mixture of *n*-butyl esters of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) containing 8.6 lb./gal acid equivalent	Mixture of undiluted technical grade esters, liquid
WHITE	Mixture consisting of triisopropanolamine salts of picloram (4-amino-3,5,6-trichloropicolinic acid) (0.54 lb./gal) and 2,4-dichlorophenoxyacetic acid (2.0 lb./gal)	Tordon 101, liquid, Dow Chemical Company
Picloram	4-amino-3,5,6-trichloropicolinic acid, potassium salt, 10% acid equivalent	Tordon 10K pellet, Dow Chemical Company
Bromacil	5-bromo-3-*sec*-butyl-6-methyluracil, 80% active ingredient	Hyvar X, 80 WP, wettable powder, E.I. du Pont de Nemours & Co., Inc.
Tandex	*meta*-(3,3-dimethylureido)-phenyl-*tert*-butylcarbamate, 10% active ingredient	Tandex 10G, granules, FMC Corporation

Treatment rates selected were the maximum rate recommended for non-selective vegetation control and twice the maximum rate. The higher rate was employed to provide a greater likelihood of herbicide movement.

Plot sites were selected in the grid area at Fort Detrick, Maryland, on the basis of uniform slope and grassy cover. Eleven plots, 20 by 20 feet square, were established on an Athol gravelly loam soil underlain at depths of 12 to 18 inches by partially decomposed red shale. Seven of these plots were on slopes of 3 to 5% and four were on slopes of 5 to 7%. The latter four plots were severely eroded. Vegetation cover was primarily Kentucky bluegrass (*Poa pratensis*) with several species of broadleaf weeds present.

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Plot applications were made on 21 May 1968 as indicated in Table 2. Liquid treatments were applied by a hand-held sprayer; granular or pellet formulations were applied by hand spreading.

TABLE 2. PLOT TREATMENT PARAMETERS

Plot No.	Chemical	Rate	Volume, gal/acre	Formulation and Diluent
3 to 5% slope				
1	WHITE	6 gal/acre	56	Liquid - water
2	Bromacil	48 lb./acre	112	Wettable powder - water
3	ORANGE	6 gal/acre	56	Liquid - diesel fuel
4	Tandex	48 lb./acre	-	10% granules
5	Picloram	15 lb./acre	-	10% pellets
6	ORANGE	3 gal/acre	28	Liquid - diesel fuel
11	Control			
5 to 7% slope				
7	WHITE	3 gal/acre	28	Liquid - water
8	Bromacil	24 lb./acre	56	Wettable powder - water
9	Tandex	24 lb./acre	-	10% granules
10	Picloram	7.5 lb./acre	-	10% pellets

Following treatment, the plots were periodically observed for down-slope movement of herbicide. Four months after application, surface soil samples (0 to 6 inches in depth) were taken from each plot and at a location 20 feet downslope of the lower boundary of each plot. Six months after application, soil cores taken in each plot were divided into depth samples of 0 to 3, 3 to 6, and 6 to 12 inches. At 1 year after treatment, samples were taken in each plot at depths of 0 to 3, 3 to 6, and 6 to 12 inches; 25 feet downslope of each plot at depths of 0 to 3 and 3 to 6 inches; and 50 feet downslope at the 0- to 3-inch depth only.

All samples except those from Tandex plots were analyzed by bioassay for herbicide content. Bromacil was determined by an oat bioassay, and WHITE, ORANGE, and picloram by a cucumber root bioassay. A suitable bioassay for Tandex was not developed.

Bioassays for bromacil were conducted in 200 g of each soil sample using 10 oat seedlings per pot, grown for 2 weeks under greenhouse conditions. Plant tops were subsequently harvested and the fresh weight was immediately measured. Bromacil concentrations were determined by

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comparing fresh top weights with those from a standard series of bromacil-treated control soils assayed concurrently with the plot samples. The method was suitable for determination of bromacil concentrations over the range of 0 to 2 ppm.

The cucumber root bioassay for WHITE, ORANGE, and picloram was a modification of the method by Parker.[11] The soil samples (30 g) were placed in plastic petri dishes (150 by 25 mm) and water (20 ml) was added. After thorough mixing the samples were allowed to equilibrate for 30 minutes. Two pieces of Whatman #1 filter paper were placed on the soil paste in each dish to absorb moisture, and 10 cucumber seeds were pressed firmly onto the filter paper. The petri dishes were incubated in darkness for 72 hours at room temperature and each viable cucumber root was measured. Herbicide concentration was determined by comparing average root length per dish with that of a standard series of plants in treated control soil. Normally the analyses were suitable over a concentration range of 0 to 5 ppm.

IV. RESULTS

A. OBSERVATIONS AT 2 WEEKS

Two weeks after treatment applications, all plots showed characteristic phytotoxic effects from the chemicals.

Plots treated with WHITE showed growth-regulator symptoms on some of the broadleaf herbaceous plants but only slight browning of perennial grasses at the higher rate. ORANGE, applied in diesel fuel, gave moderate to severe browning of grasses from the diesel fuel component. Bromacil produced moderate browning or topkill of grasses at the higher rate and a lesser overall effect at the 24 lb./acre rate on the 5 to 7% slope. Tandex gave moderate to severe browning of grasses at the higher rate of application, whereas picloram applied as 10% pellets showed little or no effect on the grasses or broadleaf vegetation at this early observation.

At the 2-week observation period slight downslope movement of WHITE and bromacil had occurred on the 5 to 7% slope (Table 3). Bromacil movement was observed as complete kill of vegetation for distances of 3 to 5 feet downslope of the lower plot boundary. WHITE mobility was indicated by growth-regulator effects on broadleaf plants for distances of 5 to 7 feet downslope.

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TABLE 3. CHEMICAL TREATMENT EXHIBITING DOWNSLOPE MOVEMENT OF HERBICIDE AT 2 WEEKS AND 4 MONTHS AS INDICATED BY PLANT RESPONSE

Plot No.	Chemical and Rate	Downslope Movement, feet 2 Weeks	4 Months
3 to 5% slope			
2	Bromacil, 48 lb./acre	-	3
5 to 7% slope			
7	WHITE, 3 gal/acre	5 to 7	-
8	Bromacil, 24 lb./acre	3 to 5	15
9	Tandex, 24 lb./acre	-	5

B. OBSERVATIONS AT 4 MONTHS

Four months after application, only the two bromacil plots and the low-rate Tandex plot showed visual signs of downslope movement (Table 3). Bromacil at 24 lb./acre had the greatest movement, a kill front moving downslope for a distance of 15 feet. The high bromacil rate also showed some downslope movement although it was limited to about 3 feet on the lesser slope. Tandex at 24 lb./acre moved downslope approximately 5 feet.

Bioassays of surface soil samples (0 to 6 inches) taken at this period 20 feet downslope of all treatments showed no herbicide present in any sample. No residue samples were taken within the treated plots at this time.

C. RESIDUE SAMPLES AT 6 MONTHS

Vertical mobility of the herbicides was investigated 6 months after treatment by analyzing soil samples from the soil layers at 0 to 3, 3 to 6, and 6 to 12 inches in each plot. Tandex plots were omitted because of the lack of a suitable method of analysis. Leaching of all herbicides was shown by analysis (Table 4). Bromacil showed the greatest vertical displacement with detectable concentrations increasing significantly with sample depth at both treatment rates. The 6- to 12-inch layer contained four to six times as much bromacil as the surface layer.

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TABLE 4. VERTICAL DISTRIBUTION OF HERBICIDES IN TREATED AREAS 6 MONTHS AFTER TREATMENT

Plot	Treatment	Sample Depth, inches	Concentration, ppm
1	WHITE, 6 gal/acre	0 - 3	2.5
		3 - 6	>3.5
		6 - 12	0.1
7	WHITE, 3 gal/acre	0 - 3	0.9
		3 - 6	0.8
		6 - 12	>5.0
3	ORANGE, 6 gal/acre	0 - 3	2.5
		3 - 6	3.1
		6 - 12	1.7
6	ORANGE, 3 gal/acre	0 - 3	2.6
		3 - 6	2.5
		6 - 12	2.8
5	Tordon 10K, 15 lb./acre	0 - 3	>5.0
		3 - 6	2.3
		6 - 12	>5.0
10	Tordon 10K, 7.5 lb./acre	0 - 3	2.0
		3 - 6	1.4
		6 - 12	1.8
2	Bromacil, 48 lb./acre	0 - 3	1.0
		3 - 6	3.0
		6 - 12	4.0
8	Bromacil, 24 lb./acre	0 - 3	0.5
		3 - 6	2.0
		6 - 12	3.0

WHITE exhibited a wide variation in residual herbicide with depth and initial rate of application. Leaching to the 6- to 12-inch level had occurred in the low-rate treatment, but at the 6 gal/acre rate, most of the residue was found in the surface 6 inches.

ORANGE showed substantial residues in the three levels sampled at both dosage levels. Tordon 10K also showed substantial amounts of residue at all three soil levels with higher amounts correlated with the higher rate of application.

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D. RESIDUE SAMPLES AT 1 YEAR.

One year after treatment, residue analyses were made to determine both lateral and vertical distribution of herbicides (Table 5).

No residues of WHITE were found either within the treated plots or at distances of 25 to 50 feet downslope at any of the sampled depths.

ORANGE was the only herbicide with detectable residue in the surface 3-inch soil layer of the treated plots. Fractional amounts were also found 25 feet downslope but not at the 50-foot distance. Picloram as Tordon 10K showed a considerable reduction in residue from the 6-month reading with no herbicide remaining in the surface 3 inches. Lateral movement downslope had occurred for a distance of 50 feet from the high-rate plot, but no traces of chemical were found downslope from the low-rate application.

Bromacil, which had shown the greatest amount of vertical movement and leaching at 6 months, occurred only in negligible amounts on the treatment plots, mostly at depths of 3 to 6 inches. No residue occurred in the surface layer. Minor residues were found at 25 and 50 feet downslope from the heavy-rate treatment only.

TABLE 5. LATERAL AND VERTICAL DISTRIBUTION OF HERBICIDES 1 YEAR AFTER APPLICATION

Plot	Treatment	Sample and Depth, inches	Concentration, ppm
1	WHITE, 6 gal/acre	Plot, 0 - 3	0
		Plot, 3 - 6	0
		Plot, 6 - 12	0
		25 feet downslope, 0 - 3	0
		25 feet downslope, 3 - 6	0
		50 feet downslope, 0 - 3	0
7	WHITE, 3 gal/acre	Plot, 0 - 3	0
		Plot, 3 - 6	0
		Plot, 6 - 12	0
		25 feet downslope, 0 - 3	0
		25 feet downslope, 3 - 6	0
		50 feet downslope, 0 - 3	0
3	ORANGE, 6 gal/acre	Plot, 0 - 3	0.3
		Plot, 3 - 6	0.2
		Plot, 6 - 12	0.3
		25 feet downslope, 0 - 3	0.5
		25 feet downslope, 3 - 6	0
		50 feet downslope, 0 - 3	0
6	ORANGE, 3 gal/acre	Plot, 0 - 3	0.4
		Plot, 3 - 6	0
		Plot, 6 - 12	0.2
		25 feet downslope, 0 - 3	0
		25 feet downslope, 3 - 6	0.2
		50 feet downslope, 0 - 3	0
5	Tordon 10K, 15 lb./acre	Plot, 0 - 3	0
		Plot, 3 - 6	0
		Plot, 6 - 12	1.9
		25 feet downslope, 0 - 3	0
		25 feet downslope, 3 - 6	>5
		50 feet downslope, 6 - 12	4.0
10	Tordon 10K, 7.5 lb./acre	Plot, 0 - 3	0
		Plot, 3 - 6	1.3
		Plot, 6 - 12	0.5
		25 feet downslope, 0 - 3	0
		25 feet downslope, 3 - 6	0
		50 feet downslope, 0 - 3	0
2	Bromacil, 48 lb./acre	Plot, 0 - 3	0
		Plot, 3 - 6	0.4
		Plot, 6 - 12	0.
		25 feet downslope, 0 - 3	0.1
		25 feet downslope, 3 - 6	0.4
		50 feet downslope, 0 - 3	0.3
8	Bromacil, 24 lb./acre	Plot, 0 - 3	0
		Plot, 3 - 6	0.7
		Plot, 6 - 12	0.2
		25 feet downslope, 0 - 3	0
		25 feet downslope, 3 - 6	0
		50 feet downslope, 0 - 3	0

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V. DISCUSSION

This limited experiment demonstrates several factors or conditions influencing the vertical and lateral mobility of herbicides in soil applications.

A. HERBICIDE CHARACTERISTICS

Relative solubility and other formulation characteristics of herbicides are important in regulating the movement of herbicides in or on soils following application to the soil surface. Of the five herbicides tested, ORANGE, consisting of esters of 2,4-D and 2,4,5-T, is lowest in solubility in water. The amine salts of 2,4-D and picloram in WHITE are highly soluble, as is the potassium salt of picloram in Tordon 10K pellet formulation (40 g/100 g of water). Bromacil and Tandex are moderately soluble in water (815 and 325 ppm, respectively).

Bromacil, applied as a wettable powder in water suspension, showed the most rapid rate of leaching and vertical movement at the 6-month sampling period. At this time, Tordon 10K pellets showed fairly high surface concentrations as well as penetration to all sampled depths, associated with the high solubility of picloram salt. Vertical leaching of both WHITE and ORANGE had also occurred by 6 months with residues occurring at all sampled levels. However, at the end of 1 year the more soluble components of WHITE had completely dissipated whereas fractional amounts of the insoluble esters in ORANGE remained, both in the treatment plot and downslope.

At the 1-year sampling date, the Tordon 10K or picloram treatment showed substantial residues downslope at distances of 25 to 50 feet from the high-rate plot. A grass cover was maintained on this plot and no visual signs of erosion were noted, indicating that movement of the herbicide was principally in solution. In contrast, the lateral displacement of bromacil by surface washing for a distance of 15 feet was evident in vegetational response observation at 4 months. No herbicide was found in surface soils sampled 20 feet downslope at this date. Movement of bromacil and Tandex is believed to have been associated with surface washing and erosion of soil particles rather than in solution and by lateral diffusion as in the case of Tordon 10K.

The persistence of ORANGE in the surface soil of treatment plots until the 1-year sampling date and its movement downslope may be attributed to the low solubility of the ester components in water as well as to the relatively slow rate of microbial degradation of the 2,4,5-T component. Barnett et al.,[6] in studies of 2,4-D losses following spray applications of esters and amines to cultivated fallow soil in Georgia, found the

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insoluble ester formulations to be retained on the soil surface and consequently subject to losses in surface runoff. In the Georgia tests involving applications at 2.2 and 4.4 lb./acre, losses were positively correlated with the rate applied. In our tests it is probable that the herbicide residues found at 6 months and 1 year consist of the more resistant 2,4,5-T component inasmuch as 2,4-D is readily decomposed by soil microorganisms.[8,9]

B. SOIL CHARACTERISTICS

The soil type of the test site was Athol gravelly loam, characterized by a relatively permeable shallow profile underlain by impervious partially decomposed red shale at depths of 12 to 18 inches. This impervious layer retarded downward percolation and created a zone in which herbicides tended to accumulate. Had not this restrictive layer been present, the herbicides would probably have percolated to greater depths.

C. EFFECT OF SLOPE

Only limited generalizations can be made on the effect of slope, as the two dosage levels of herbicide were not replicated on the two slope gradients. With the exception of ORANGE, the heavy rate of each herbicide was applied on the 3 to 5% slope and the light rate on the 5 to 7% slope. Both treatments of ORANGE were on the 3 to 5% slope.

Lateral displacement of WHITE, bromacil, and Tandex applied at the light rate took place on the steeper 5 to 7% slope as shown in the 2-week and 4-month observations. At 4 months, however, none of the treatments showed a residue in the surface soil 20 feet downslope of the plot boundary.

Lateral movement of bromacil appeared to occur after the rapid topkill of grass. Its movement was associated with the increased erosion noted after the death of grass cover. On the other hand, picloram as Tordon 10K pellets did not kill the grass but residual amounts were found at a distance of 50 feet from the plot border at the 1-year sampling period.

At the end of the 1-year period no evidence of WHITE was found either in the treatment plot or at downslope locations. ORANGE, applied in diesel fuel solutions, was residual in minute amounts at the 1-year sampling both in the treated profile and at a 25-foot downslope location. The relatively large volumes of diesel fuel used in the application of ORANGE caused an initial topkill of grasses and may have enhanced percolation of the herbicide at the time of application. The lateral displacement of ORANGE is attributed to the 2,4,5-T component, which is more resistant to microbial decomposition than 2,4-D. No lateral movement attributable to volatility of ORANGE was noted.

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D. EFFECT OF RATE

As previously stated, with the exception of the herbicide ORANGE, application rates were confounded with the slope variable so that only limited generalizations can be made of the effects of rate.

Six months after application of ORANGE, residues were found uniformly throughout the soil profile and showed no significant difference at the two dosage levels. At the end of 1 year, trace amounts remained both in the plots and at 25 feet downslope at the two rates of application.

Greater amounts of residual herbicide were observed at the higher rate of application of picloram as Tordon 10K at the 6-month period. WHITE, containing both picloram and 2,4-D, also showed higher residues in the surface 6 inches from applications at the higher rate, although the reverse situation was true in the 6- to 12-inch soil profile.

The effects of initial difference in rate of application were still evident at 1 year in the case of Tordon 10K and bromacil by greater downslope displacement from the heavy-rate treatments despite their low slope gradients. An additional rate comparison is provided with WHITE and Tordon 10K. The picloram component of WHITE was 1.62 and 3.24 lb./acre, respectively, at low and high rates of application compared with 7.5 and 15 lb./acre of picloram as Tordon 10K, or a difference of fivefold. At the 1-year sampling period the heavier rates of Tordon 10K resulted in detectable residues in contrast to the negative samples from WHITE.

E. PERSISTENCE AND DEGRADATION

The present experiment generally confirms previous work on the persistence, leaching, and degradation of herbicides. Of the herbicides tested, picloram is known to be relatively persistent because of its low biodegradability. At the end of 1 year, the heavy-rate treatment with picloram or Tordon 10K showed the highest residue in the treatment plot and downslope from the treated area. It is of interest, however, that WHITE with its lower content of picloram showed no residue at the end of the year at either location.

Bromacil apparently undergoes microbial degradation and its losses due to leaching and degradation gave negligible residues by the end of the year.

ORANGE, when applied at rates equivalent and double that of defoliation for tropical vegetation, gave minor residues throughout the treatment plot profiles and at 25 feet downslope at the end of 1 year after treatment. Early work at Fort Detrick and other locations has established the relatively rapid rate of decomposition of 2,4-D in contrast to 2,4,5-T.[7,8] It may be assumed that the residues found after 1 year are composed of 2,4,5-T.

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VI. SUMMARY

Bioassay techniques were used to assess the mobility and persistence of four herbicides applied to grassland vegetation on various slopes: ORANGE, WHITE, bromacil, and picloram. Limited observations were also made of the lateral movement of Tandex on the basis of vegetation response only. Application rates used were normal and double the normal rate used in defoliation and vegetation control.

Bromacil showed the most rapid rate of leaching and vertical movement at the 6-month sampling period. Lateral movement downslope occurred within 2 weeks after application, and trace amounts were still present 50 feet downslope 1 year after application at the heavy rate.

Picloram, as potassium salt, showed relatively rapid leaching within the soil profile. At 1 year, no picloram residues were found in the surface soil but significant lateral displacement had occurred to a distance of 50 feet from the heavy-rate application.

ORANGE was uniformly distributed within the soil profile at 6 months, and trace amounts remained in the surface soil from both rates of application at the end of 1 year. It is assumed that the residual material consists of 2,4,5-T, as the 2,4-D component of ORANGE is readily decomposed by soil microorganisms.

WHITE exhibited a wide variation in residual herbicide at 6 months, but had completely dissipated by 1 year after application.

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13. ABSTRACT

Bioassay techniques were used to evaluate the lateral and vertical movements of herbicides ORANGE, WHITE, picloram, and bromacil following application to grassland vegetation on a gravelly loam soil. Picloram and bromacil exhibited vertical and lateral mobility; residual amounts of each herbicide were recovered 1 year after application 50 feet down-slope from heavy-rate treatments. Trace amounts of ORANGE were found in the surface soil at 1 year, but WHITE had completely dissipated in this period.

14. Key Words

Herbicide persistence
Herbicide movement
ORANGE
WHITE
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Bromacil
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Dr. [redacted], Dr. [redacted] and Dr. [redacted] of the Agricultural Research Service assisted in the Puerto Rico tests. Dr. [redacted] of the University of Hawaii Agriculture Experiment Station carried out the Hawaii tests.

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[redacted] and [redacted] of Physical Sciences Division at Fort Detrick assisted in the development of formulations and preparation of field test mixtures. [redacted], of Physical Sciences Division supplied data on physical characteristics of candidate defoliants and mixtures.

Civilian personnel of the Plant Physiology Division contributing to the project included [redacted] and [redacted] of Transportation Division assisted in CONUS field test applications. Military personnel participating in the project were [redacted] and [redacted]

In addition to the chemical companies providing materials under contract, chemicals were furnished gratuitously or by purchase from the following companies: Air Products and Chemicals Company, Ansul Company, Chevron Chemical Company, Colloidal Products Company, Dow Chemical Company, and Pennwalt Company.

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ABSTRACT

Field evaluations were made of the rapidity and duration of defoliation of commercial desiccants, improved formulations, and desiccant-herbicide mixtures from aerial applications at temperate and tropical forest sites. Chemicals tested included ORANGE, BLUE, dinitrobutylphenol (DNBP), diquat, paraquat, pentachlorophenol (PCP), hexachloroacetone, and combinations of various chemicals with picloram, ORANGE, or 2,4,5-T.

No candidate chemical gave effective defoliation within 10 days after application, but BLUE was superior to most desiccants. At 30 days, defoliation from BLUE, diquat, paraquat, DNBP, and PCP was equal or superior to that from the standard ORANGE at 3 gallons per acre.

Mixtures of ORANGE and desiccants gave more rapid desiccation but no improvement in defoliation. Picloram + paraquat and WHITE or picloram + 2,4-D were effective long-term defoliants at both tropical and temperate sites. In general, tropical species showed better and more rapid defoliation than temperate species.

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APPENDIXES

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I. INTRODUCTION*

During the period December 1966 to October 1967 a comprehensive short-term program was undertaken to evaluate desiccants and herbicidal mixtures as rapid-acting defoliants. Intensive screening of commercially available desiccants, development of improved formulations, and field evaluation of desiccants and mixtures with systemic herbicides were conducted by personnel of the Plant Sciences Laboratories at Fort Detrick in coordination with contract research on formulations by chemical industry and field tests by the U.S. Department of Agriculture and the University of Hawaii.[1]

Currently used defoliants, including agents ORANGE and WHITE, are systemic herbicides that cause desiccation and browning of foliage in 7 to 10 days. Abscission or defoliation under tropical conditions may not occur until 1 to 2 months after application of the chemical. Objectives of the current study were to evaluate rapid-acting desiccants as defoliants and to assess the defoliation response of woody vegetation to mixtures of herbicides and/or desiccants. Criteria for assessment were based principally on rapidity of action but included other features such as safety and ease of handling, compatibility with dissemination systems, and low toxicity to man and wildlife. Ideally, the selected defoliant should be capable of effective defoliation of temperate or tropical forest vegetation within a period of 7 to 10 days or less.

The approach to the objective of an improved rapid-acting defoliant involved three phases: (i) evaluation of commercially available rapid desiccants or contact herbicides; (ii) evaluation of improved formulations of rapid desiccants developed under industry contracts and by in-house effort; (iii) development and evaluation of desiccant/herbicide mixtures combining rapid defoliant characteristics with the sustained long-term effects of ORANGE and other defoliants. Support was furnished in phases (ii) and (iii) by formulation contracts involving four commercially available desiccants: cacodylic acid and/or sodium cacodylate (agent BLUE), dinitrobutylphenol (DNBP), pentachlorophenol (PCP), and hexachloroacetone (HCA).**

Other basic desiccants selected for assessment either alone or in mixtures with other herbicides included paraquat, diquat, endothall, and AP-20. Systemic herbicides used for comparison and formulation mixtures included ORANGE, 2,4,5-T, and picloram or Tordon.

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* This report should not be used as a literature citation in material to be published in the open literature.

** A complete list of chemicals used in the program is given in Appendix A.

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II. PROCEDURE

A. IN-HOUSE

The basic procedure consisted of three series of aerial applications at test locations in Florida, Georgia, and Arkansas coordinated with laboratory formulation, screening, and small field-plot testing of candidate chemicals and mixtures. Test locations were selected at: Fort Gordon near Augusta, Georgia; Fort Chaffee near Fort Smith, Arkansas; and Apalachicola National Forest near Sopchoppy, Florida. An additional aerial field test in a conifer-hardwood forest at Base Gagetown, New Brunswick, Canada, conducted by Fort Detrick personnel provided supplemental information.[2] Site characteristics and major plant species for the CONUS test locations are given in Appendixes B and C.

1. Aerial Tests and Evaluations

Scope and date of the three series of aerial test applications were as follows:

1) Preliminary evaluation of basic desiccants and ORANGE:

Florida: 3-8 May 1967
Arkansas I: 16-18 May 1967
New Brunswick, Canada: 20-24 June 1967

2) Evaluation of in-house desiccant mixtures and formulations:

Georgia: 15-17 July 1967
Arkansas II: 22-23 July 1967

3) Evaluation of selected improved formulations from three contracts and in-house candidate agents:

Arkansas III: 23-25 August 1967

Aerial applications at the three CONUS sites were made with a Bell G-2 helicopter equipped with two 40-gallon tanks and a 26-foot boom with 6-inch nozzle positions adaptable for volume deliveries of 3, 6, or 10 gallons per acre in a 50-foot swath. Spray equipment, pilot, and support were furnished under contract with Allied Helicopter Service of Tulsa, Oklahoma. A similar contract and service were supplied for the Base Gagetown, Canada, test by the Okanagan Copter Sprays, Ltd., of Vancouver, British Columbia.

Aerial applications were made on duplicate 3-acre plots, 200 by 660 feet in dimension. A sampling and evaluation trail was established in each plot on a diagonal beginning at 100 feet from one corner. Major

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species were marked along 500 feet of this transect and individual plants were identified by combinations of colored plastic ribbons. A minimum of 10 individuals of each species was marked unless fewer were present.

Evaluations were made at 1-, 5-, 10-, 30-, and 60-day intervals by experienced observers. At each evaluation period the identical marked individuals of the major species were rated for defoliation and desiccation on a rating scale of 0 to 5 (complete effect). Abscission or defoliation was rated separately from desiccation (browning and drying). In compilation of data, defoliation and desiccation ratings for each species were converted to per cent and treatment means were calculated as the average of all species present.

2. Screening and Preliminary Field Test

Selection of candidate chemicals for the aerial test applications in phases 2) and 3) were based on greenhouse screening and field plot trials conducted at the Florida and Arkansas locations in May, June, and July by means of the cherrypicker, or high boom sprayer.[3] A total of 94 new formulations and mixtures were prepared for initial screening and field test programs by a chemist and technician from Physical Sciences Division.

B. CONTRACT RESEARCH

1. Formulation Contracts

Formulation and evaluation contracts were established with three chemical companies to develop improved formulations of DNBP, PCP, and HCA with high concentrations of active ingredient and rapid defoliant action. Evaluations of cacodylic acid analogs were made independently by Ansul Company under a related formulation contract, but no formulations superior to agent BLUE were found. Contract arrangements with the following three companies called for delivery of 150-gallon lots each of three improved defoliant formulations for field testing.

a. Allied Chemical Corporation

The Allied Chemical Corporation prepared formulations of HCA and mixtures of HCA with active desiccants and defoliants.[4] Sixty-two formulations were evaluated in greenhouse tests on California privet (Ligustrum ovalifolium Hassk.) and Kurume azalea (Rhododendron amoenum Planch.). Three active formulations selected for aerial field tests consisted of: HCA/2,4-D, HCA/linuron, and HCA/silvex mixtures. A commercially available mixture of HCA and 2,4,5-T was included in initial aerial tests.

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b. Dow Chemical Company

Under the contract with Dow Chemical Company, improvement of the effectiveness of DNBP was sought by increasing the amount of active ingredient per gallon and formulating a desirable surfactant-solvent system.[5] Over 300 formulations were evaluated on bean plants and 140 of the most active formulations were tested on California privet and Chinese elm (Ulmus parvifolia Jacq.). The three most active formulations of DNBP, diesel oil, and other adjuvants were submitted in 150-gallon lots for use in the aerial spray tests in Arkansas.

c. Monsanto Company

The contract with Monsanto Company had as its primary objective formulation of oil-soluble and emulsifiable concentrates of PCP and PCP-herbicide/desiccant mixtures.[6] A total of 79 formulations and mixtures with 15 herbicides and desiccants were tested by the contractor on amur privet (Ligustrum amurense Carr.) and Japanese holly (Ilex crenata Thurb. var. rotundifolia Hort.).

2. OCONUS Field Tests

Coordinated OCONUS field tests were established under contract with the Crops Protection Research Branch, Agricultural Research Service, U.S. Department of Agriculture, at Mayaguez, Puerto Rico, and the University of Hawaii at the Kauai Branch Experiment Station, Hawaii. Chemicals were furnished by Fort Detrick for aerial tests at the two locations to provide information on defoliation responses of tropical forest vegetation.

a. Puerto Rico

Due to limitation in suitable equipment and locations for aerial tests, the program at this location consisted principally of extensive field trials with candidate chemicals and mixtures with a telescoping pole sprayer capable of overhead spray delivery on circular plots 40 feet in diameter. Treatments were made at nine intervals from February to December 1967 on guava (Psidium guajava L.). On each plot five or six trees were evaluated for per cent defoliation and desiccation at 3, 7, and 14 days and at monthly intervals after treatment.[7,8]

Aerial applications of 16 chemical treatments were made September 1967 at Las Marias, Puerto Rico, on a mixed forest using a Bell G-2 helicopter provided by Allied Helicopter Service. The plots were 1½ acres in size, and approximately 50 trees on each plot were numbered at random and evaluated for degree of defoliation and desiccation. A list of the principal woody species on the test site is given in Appendix E.

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b. Hawaii

Four series of aerial tests were conducted near the Kauai Branch Station of the Hawaiian Agricultural Experiment Station on tropical woody and forest vegetation.[9] Applications were made by fixed-wing plane on replicate 2-acre plots, and evaluations were secured at weekly and monthly intervals for periods of 4 to 6 months. Dates and features of the four series were as follows:

1) Basic desiccants, July 1967; 16 treatments at 10 to 20 gallons per acre.

2) Basic desiccants, October 1967; 14 treatments at 3 to 6 gallons per acre.

3) Improved desiccants and mixtures, February 1968; 14 treatments at 6 gallons per acre.

4) Systemic herbicides and combinations, December 1967; 19 treatments at 3 and 6 gallons per acre.

Common and botanical names of the principal woody species at the Hawaii test site are given in Appendix F.

III. RESULTS

A. CONUS FIELD TESTS

1. Basic Desiccants

Ratings of per cent defoliation and combined defoliation/desiccation from the first two series of aerial tests in Florida, Georgia, and Arkansas are given in Table 1 for commercially available formulations of desiccants in comparison with ORANGE.

TABLE 1. PER CENT DEFOLIATION AND PER CENT DEFOLIATION PLUS DESICCATION FROM AERIAL APPLICATION OF BASIC DESICCANTS AND ORANGE

Chemical	Rate, lb./acre	Vol, gal/acre	No. of Tests	% Defol./% Defol. + Desic. 5 Days	10 Days	30 Days	60 Days
BLUE	9	3	2	1/8	3/15	4/22	14/24
	12	6	3	2/40	9/68	30/65	39/68
	18	6	4	2/29	15/53	23/59	23/46
	24	10	4	4/44	16/63	26/68	20/47
Diquat	6	3	2	5/21	11/37	14/36	24/40
	12	6	4	3/35	10/53	18/56	22/42
Paraquat	6	3	2	8/32	14/50	23/53	37/53
	12	6	4	2/20	7/47	17/53	29/52
DNBP	6	3	1	6/26	6/32	10/28	14/26
	12	6	1	8/28	8/28	15/30	22/33
	18	4	1	4/36	6/58	18/52	14/29
	24	10	1	6/66	12/63	18/51	24/47
	35	6	1	6/74	12/77	16/41	12/30
	50	10	1	2/60	6/78	30/65	34/58
PCP	12	3	4	3/36	4/49	16/48	24/48
	18	6	2	1/52	5/61	22/67	16/51
	24	6	1	6/24	6/36	19/68	32/54
	27	6	2	4/38	12/56	18/38	12/26
	40	10	1	2/24	8/42	18/44	28/41
ORANGE	26	3	5	2/40	4/48	23/76	46/81

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Maximum defoliation during the first 10 days was 15 to 16% for BLUE applied at 18 to 24 lb. per acre. DNBP applied at 24 to 30 lb. per acre gave the highest rate of desiccation (63 to 78%) within 5 days after treatment. By 1 month, BLUE still showed maximum defoliation for the group with a mean of 30% for 12 lb. per acre. By 60 days, ORANGE had surpassed all desiccants in per cent defoliation and combined defoliation-desiccation.

Seasonal and location comparisons of BLUE and ORANGE treatments presented in Table 2 show BLUE to be slightly superior in defoliation through the 30-day period. By 60 days, ORANGE gave a mean defoliation of 46% compared with 34% for BLUE.

TABLE 2. PER CENT DEFOLIATION AND PER CENT DEFOLIATION PLUS DESICCATION FROM AERIAL APPLICATIONS OF BLUE AND ORANGE AT FIVE CONUS LOCATIONS

		% Defoliation/% Defoliation + Desiccation				
Location	Date	5 Days	10 Days	30 Days	60 Days	1 Year
		BLUE (12-18 lb./acre)				
Florida	May 3-8	2/8	28/50	16/56	40/64	-a/
Arkansas I	May 16-18	0/22	16/55	24/52	20/36	-
Georgia	Jul 15-17	0/46	11/64	33/68	20/49	33
Arkansas II	Jul 22-23	1/27	2/47	21/56	18/38	-
Arkansas III	Aug 23-25	6/58	18/79	34/71	70/93	-
Mean		2/32	15/59	28/61	34/56	-
		ORANGE (26 lb./acre)				
Florida	May 3-8	2/14	4/18	6/42	44/69	54
Arkansas I	May 16-18	4/16	8/46	30/83	48/84	70
Georgia	Jul 15-17	0/18	2/36	40/81	42/80	57
Arkansas II	Jul 22-23	2/52	6/80	16/80	38/76	68
Arkansas III	Aug 23-25	0/46	2/62	22/83	60/91	70
Mean		2/39	4/48	23/76	46/80	64

a. Data unavailable.

No significant trends were noted in defoliation response as related to season of application. The relatively high defoliation values for BLUE and ORANGE at 60 days in the Arkansas III test include some natural defoliation associated with the late season application. The short-term defoliation response to BLUE is evident in the lack of ratings at the 1-year interval as compared with ORANGE.

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2. Improved Formulations

Defoliation and desiccation ratings on improved formulations from contract sources and single tests of other desiccants are presented in Table 3.

TABLE 3. PER CENT DEFOLIATION AND PER CENT DEFOLIATION PLUS DESICCATION FROM AERIAL APPLICATIONS OF IMPROVED DESICCANT FORMULATIONS

Chemical	Rate, lb./acre	Vol, gal/acre	% Defol./% Defol. + Desic. 5 Days	10 Days	30 Days	60 Days
PCP						
PCP	18	6	2/54	14/64	28/50	54/74
PCP + nitrophenol	12 + 3	6	2/50	16/68	28/62	56/75
PCP + propanil	12 + 12	6	6/56	20/65	32/56	56/71
DNBP						
M 3257	12	10	4/72	18/87	26/51	44/70
M 3260	12	10	4/64	14/76	24/56	60/80
M 3261	12	10	4/76	14/79	32/49	56/79
HCA						
HCA + 2,4-D	6 + 6	6	0/6	6/44	28/68	66/92
HCA + silvex	6 + 6	6	0/2	4/34	26/55	66/92
HCA + linuron	6 + 6	6	2/8	10/40	38/62	54/69
HCA + 2,4,5-T	6 + 6	6	0/22	2/44	22/67	68/95
AP-20						
AP-20	4	6	4/34	8/58	24/42	56/68
AP-20	8	6	4/48	28/80	28/57	78/85
AP-20 [a]	12	6	2/58	2/64	16/63	20/52
Endothall						
Endothall	3	6	8/66	18/72	22/63	54/76
Endothall + paraquat	3 + 1	6	0/46	20/71	30/61	54/81
ORANGE	26	3	0	2/62	22/81	60/91

a. Applied on July 22-23, 1967; other AP-20 treatments made August 23-25, 1967.

Maximum defoliation of [illegible] within the first 10 days was produced by AP-20 at 8 lb. per acre. At 5 days, the improved formulations of PCP, DNBP, and endothall had given more than 50% desiccation, with DNBP causing the most rapid response within 1 day of application. Under the drought conditions of this late August test, ORANGE applied at 3 gal per acre produced strong early desiccation comparable to that from PCP formulations.

By the end of 30 to 60 days, none of the improved formulations gave significantly more defoliation than ORANGE, with the exception of AP-20 at 60 days. Effective defoliation (60% or more) was not obtained with any chemical until 2 months after application.

3. Desiccant-Herbicide Mixtures

Evaluations of defoliant and desiccation activity of combinations of desiccants with other herbicides are presented in Tables 4 and 5. None of the mixtures of ORANGE or 2,4-D/2,4,5-T esters with various desiccants shown in Table 4 gave effective defoliation within 30 days after treatment. At 10 days, mixtures with DNBP, AP-20, endothall, and the benzenesulfonyl fluorides 41256 and 41414 gave significantly greater defoliation and desiccation activity than ORANGE alone. The combinations of ORANGE + AP-20 and ORANGE + 41414 showed the most rapid desiccation activity as indicated by the 5-day ratings. At 60 days, the combinations of ORANGE with AP-20 (13 + 6 lb. per acre), endothall, and the benzenesulfonyl fluorides gave 60% or more defoliation. These tests were all conducted at the Arkansas III location in late August 1967, and the 60-day observations include some natural seasonal defoliation. It should be noted that the treatment with ORANGE (26 lb. per acre) at this location gave 60% defoliation for the same period. Defoliation ratings taken at the end of 1 year showed a reduction in defoliation response on the ORANGE-desiccant mixtures in comparison with a single application of ORANGE. Additional information on the tests with the benzenesulfonyl fluorides 40845, 41256, and 41414 is given by Popoff et al.[10]

Tests conducted at the Florida and Arkansas I locations of the combination of monosodium methanearsonate (MSMA) with 2,4-D/2,4,5-T amine salt showed no advantage in either early- or long-term defoliation over ORANGE.

As shown in Table 5, combinations of BLUE with other desiccants such as paraquat and AP-20 gave slightly better defoliation at 30 days and significantly greater desiccation than BLUE alone. The 60-day rating of 66% defoliation for the combination BLUE + AP-20 is attributable in part to natural defoliation from the late-season application. The combination of BLUE and ORANGE, achieved by use of a surfactant* gave similar defoliation but slightly more desiccation at 30 and 60 days than BLUE alone.

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* L-251, Colloidal Products Company. The assistance of this company in furnishing several surfactants used in formulation studies is acknowledged.

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TABLE 4. PER CENT DEFOLIATION AND PER CENT DEFOLIATION PLUS DESICCATION FROM AERIAL APPLICATIONS OF HERBICIDE MIXTURES CONTAINING ORANGE OR 2,4-D/2,4,5-T AMINE SALTS

Chemical	Rate, lb./acre	Vol, gal/acre	No. of Tests	% Defoliation/% Defoliation + Desiccation				
				5 Days	10 Days	30 Days	60 Days	1 Year
ORANGE	26	3	5	2/39	4/48	23/76	46/80	64
ORANGE + DNBP	13 + 12	6	2	0/60	1/76	22/71	25/75	40
ORANGE + PCP	13 + 18	6	3	4/47	8/69	30/81	39/71	37
ORANGE + BLUE	17 + 12	10	2	1/54	5/68	28/83	32/79	52
ORANGE + AP-20	26 + 12	10	1	2/72	4/82	26/90	28/84	48
ORANGE + AP-20	13 + 6	6	1	4/68	6/78	26/69	66/93	-[a]
ORANGE + endothall	13 + 6	6	1	2/50	6/74	29/71	66/89	-
ORANGE + 40845	18 + 3	6	1	2/44	2/50	16/80	68/92	-
40845	3	6	1	0/42	6/60	18/48	54/69	-
ORANGE + 41256	18 + 3	6	1	2/46	14/71	22/90	74/95	-
41256	3	6	1	2/40	2/60	26/48	68/76	-
ORANGE + 41414	18 + 3	6	1	16/76	18/92	30/98	72/96	-
41414	3	6	1	10/70	8/62	34/70	60/78	-
2,4-D/2,4,5-T + MSMA	1.5/1.5 + 6	3	1	4/14	8/32	8/40	36/48	0
2,4-D/2,4,5-T + MSMA	3/3 + 12	6	2	5/24	3/30	7/45	28/44	20
2,4-D/2,4,5-T + MSMA	5/5 + 20	10	2	4/23	5/44	20/62	38/62	25

a. Data unavailable.

TABLE 5. PER CENT DEFOLIATION AND PER CENT DEFOLIATION PLUS DESICCATION FROM AERIAL APPLICATION OF DEFOLIATION-DESICCANT MIXTURES CONTAINING BLUE, PICLORAM, AND 2,4,5-T

Chemical	Rate, lb./acre	Vol, gal/acre	No. of Tests	% Defoliation/% Defoliation + Desiccation				
				5 Days	10 Days	30 Days	60 Days	1 Year
BLUE	12 to 18	6	5	2/32	15/59	23/61	34/56	-a/
BLUE + diquat	12 + 6	10	2	1/63	3/75	21/69	22/61	-
BLUE + paraquat	12 + 6	10	2	2/69	7/84	37/84	26/68	-
BLUE + picloram K salt	12 + 4	6	1	0/50	6/76	30/82	24/70	-a/
BLUE + AP-20	6 + 6	6	1	8/60	20/76	44/76	66/82	-
BLUE + ORANGE	12 + 17	6	2	1/54	5/68	28/83	32/79	52
Picloram + 2,4-D (WHITE)	1.5 + 6	3	2	0/18	3/41	32/80	29/78	75
Picloram K salt + BLUE	4 + 12	6	1	0/50	6/76	30/82	24/70	48
Picloram K salt + paraquat	4 + 6	6	2	1/43	4/66	27/88	29/89	93
Picloram ester + PCP + HCA	4 + 12 + 26	6	2	0/43	1/51	18/75	22/62	26
2,4,5-T + HCA	6 + 6	6	1	0/22	2/44	22/67	68/95	30
2,4,5-T + HCA	12 + 12	6	2	7/32	8/45	21/59	55/74	61
2,4,5-T + HCA	20 + 20	10	2	1/27	4/39	32/68	50/74	49

a. Data unavailable.

6845

Combinations of picloram with other herbicides and desiccants did not give effective defoliation by 60 days after treatment. At 1 year the combination of picloram + paraquat (4 + 6 lb./acre) gave the highest degree of defoliation (93%) of any chemical tested. The next best treatment was picloram + 2,4-D or WHITE with a mean rating of 75% defoliation at two locations.

The combination of HCA and 2,4,5-T gave variable defoliation response and was only minimally effective at the end of 1 year.

4. Species Response to Desiccants and Mixtures

Table 6 presents a résumé of species susceptibility to selected desiccants and desiccant-herbicide mixtures based on the CONUS field tests.

The three southern conifers were generally resistant or intermediate (delayed) in susceptibility to desiccants or herbicide mixtures. For example, picloram plus paraquat gave delayed defoliation of both loblolly and longleaf pines. Other mixtures, including paraquat and BLUE, had a rapid desiccating action on conifers.

Broadleaf evergreens were susceptible principally to paraquat and to HCA + 2,4,5-T. ORANGE was moderately effective on this group except for southern magnolia and laurel oak.

Deciduous species were variable in response to the array of chemicals ranging from the moderately resistant post oak to the susceptible persimmon. Blackgum was susceptible to ORANGE and the HCA + 2,4,5-T combination but resistant to all desiccants and picloram mixtures. ORANGE and HCA + 2,4,5-T were effective defoliants on the largest number of species. BLUE and paraquat failed to give overall effective defoliation within 60 days and were highest in the number of resistant species. Picloram + paraquat had the maximum number of species with a delayed or intermediate defoliation response.

B. CANADA FIELD TESTS

During the period 21-24 June 1967, aerial applications of desiccants and herbicides were made in a conifer-hardwood forest at Base Gagetown, near Fredericton, New Brunswick. The test was curtailed in scope from that originally planned due to unseasonably late freezing temperatures causing delayed foliation and scheduling restrictions so that only partial rate comparisons of various desiccant and herbicide-desiccant mixtures are available. A preliminary report on this test covering evaluations through the 90-day period is available in Technical Memorandum 145.[2] This study presents additional data and subsequent 1-year evaluations of this test.

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TABLE 6. SPECIES RESPONSE[a/] TO SELECTED DEFOLIANTS AND DESICCANTS IN CONUS TEST

Species	ORANGE	ORANGE + PCP	BLUE	WHITE	Paraquat	Picloram + Paraquat	2,4,5-T + HCA	2,4-D/2,4,5-T + MSMA
Conifers								
Pine, loblolly	R	R	I	I	R	I	-	-
Pine, longleaf	R	R	R	R	R	I	-	-
Pine, spruce	R	-	R	-	S	-	R	R
Broadleaf Evergreens								
Bayberry, southern	S	-	R	-	R	-	S	S
Holly, American	I	I	R	I	S	-	I	R
Magnolia, southern	R	I	R	I	S	-	I	R
Oak, bluejack	S	I	S	S	S	I	-	-
Oak, laurel	R	-	S	-	S	-	S	S
Oak, water	-	-	R	-	S	S	S	-
Sparkleberry	S	S	S	S	S	S	-	-
Sweetbay	S	-	S	-	R	-	S	S
Deciduous								
Ash, white	R	R	S	R	S	S	S	R
Blackgum	S	R	R	R	R	R	S	R
Dogwood, flowering	I	R	R	I	R	I	-	-
Elm, winged	S	S	R	S	R	S	S	S
Hawthorn	S	S	R	R	R	S	S	R
Hickory, mockernut	I	S	R	R	-	I	I	-
Hophornbeam, eastern	S	-	R	-	R	-	S	S
Hornbeam, American	I	-	S	-	S	S	-	R
Locust, honey	S	S	S	R	R	R	S	S
Mulberry, red	S	S	S	S	S	I	R	S
Oak, black	I	-	R	I	R	I	I	-
Oak, blackjack	S	R	R	I	R	I	S	R
Oak, post	I	R	R	I	R	I	I	R
Oak, sand post	I	R	R	R	S	I	-	-
Oak, southern red	I	-	R	I	R	I	I	-
Oak, swamp chestnut	R	-	R	-	S	-	I	R
Oak, turkey	R	R	R	I	S	I	-	-
Persimmon	S	S	S	S	S	S	S	S
Sweetgum	I	R	S	R	R	I	S	R
Sumac, shining	I	S	S	S	R	I	S	S

a. S = susceptible, 60% or more defoliated within 2 months; I = intermediate, 60% or more defoliated at 1 year; R = resistant, less than 60% defoliated; - = no rating available.

6847

In Table 7, defoliation ratings are presented for conifers and broadleaf deciduous trees or hardwoods at the 60-day, 90-day, and 1-year evaluation periods for all treatments applied. Of the desiccant group, maximum defoliation was caused by paraquat at 6 lb. per acre with a hardwood defoliation of 46% at 90 days and 82% in the year after treatment. BLUE, diquat, and PCP gave moderate defoliation of hardwoods at 90 days but were not effective at 1 year. These chemicals showed little or no effect on conifers. DNBP gave negligible response on both conifers and broadleaf species.

TABLE 7. PER CENT DEFOLIATION OF HARDWOOD AND CONIFER SPECIES FROM AERIAL APPLICATIONS OF DESICCANTS AND HERBICIDES AT BASE GAGETOWN, NEW BRUNSWICK, CANADA, 1967

Chemical	Rate, lb./acre	60 Days		90 Days		1 Year	
		Hdw.	Con.	Hdw.	Con.	Hdw.	Con.
Desiccants							
BLUE	9.3	3	9	22	16	50	1
Diquat	6	4	14	30	19	54	14
Paraquat	6	26	6	46	23	82	5
DNBP	12	0	4	14	6	0	0
PCP	15	5	1	30	1	12	0
Herbicides and Combinations							
ORANGE	26	7	14	48	0	99	4
2,4,5-T + HCA	6 + 6	2	0	38	18	74	0
2,4-D	24	5	3	42	3	89	31
Picloram + 2,4-D (WHITE)	1.5 + 6	0	21	18	15	94	56
Picloram K salt + diquat	2 + 2	9	13	32	13	85	81
	3 + 3	2	23	58	20	100	100
Picloram K salt, + paraquat	2 + 2	11	21	44	33	66	60
	3 + 3	11	26	56	27	86	62
Picloram K salt	3	4	38	52	5	83	91
	4.5	2	21	42	13	97	85
	6	0	31	44	17	90	75
Picloram ester	6	2	1	32	5	62	42
	12	8	6	18	8	91	7

6848

At the standard rate of 3 gal per acre, ORANGE gave moderate defoliation (48%) of hardwoods at 90 days. At 1 year, defoliation was essentially complete. Conifers showed slight defoliation but had recovered by 90 days. The data for HCA + 2,4,5-T and 2,4-D ester are indicative of the defoliation responses to the two components of ORANGE: 2,4,5-T and 2,4-D esters. Both showed a delayed effect on hardwoods until 1 year; the 2,4-D ester alone gave 31% defoliation of conifers versus a negligible defoliation by HCA + 2,4,5-T.

Combinations of diquat or paraquat with picloram as potassium salt were effective defoliants of both hardwoods and conifers but showed delayed response. At 90 days, defoliation at the heavier rate (3 + 3 lb. per acre) of both mixtures approached the minimally effective level on hardwoods. Comparable delayed defoliation was obtained on conifers and hardwoods with the picloram salt applied singly at 3, 4.5, and 6 lb. per acre. The ester of picloram appeared to be effective on hardwoods but not on conifers. Agent WHITE, the combination of picloram + 2,4-D, also gave delayed but nearly complete defoliation of hardwoods and a moderately severe effect on conifers.

Susceptibility or resistance of the important hardwood and conifer species to the desiccants and herbicides is given in Table 8. Common and botanical names of the species at this test site are given in Appendix D. Aspen was the most susceptible and red maple the most resistant of the hardwood species. Conifers were generally resistant to most chemicals. American larch showed susceptibility to the greatest number of chemicals, including the desiccants.

C. OCONUS FIELD TESTS

Aerial application tests conducted by contractors in tropical forests in Hawaii and Puerto Rico partially duplicated the array of desiccants and desiccant-herbicide mixtures evaluated in the CONUS field program. A more comprehensive array of treatments was tested in Hawaii than in Puerto Rico. Botanical composition data for the two test locations are given in Appendixes E and F.

Comparative defoliation ratings are shown in Table 9 for ORANGE and the basic desiccants at the two tropical locations and in the CONUS tests. Ratings were made for periods up to 4 to 6 months in Hawaii and for 6 months at Puerto Rico. Comparable data for the first 2 months only are available for the CONUS tests.

6849

TABLE 8. SPECIES RESPONSE[a] TO SELECTED DESICCANTS AND HERBICIDE MIXTURES AT BASE GAGETOWN TESTS

Species	BLUE	Diquat	Paraquat	PCP	DNBP	ORANGE	2,4-D	2,4,5-T + HCA	WHITE	Picloram + Diquat	Picloram + Paraquat	Picloram K Salt	Picloram Ester
Conifers													
Fir, balsam	R	R	R	R	R	R	R	R	I	I	R-I	I	R-I
Larch, American	S	S	S	R	R	-	-	S	R	R	S	I	R
Pine, white	R	R	R	R	R	-	I	R	R	R	R	R	R
Spruce, white	R	R	R	R	R	R	R	R	R	I	R-I	I	R
Hardwoods													
Alder, speckled	R	I	I	R	I	I	I	I	I	I	R-I	I	I
Aspen, quaking	R	I	S	R	R	I	S	I	S	S	S	I	I
Birch, grey	R	R	S	R	R	I	I	I	I	I-S	I	I	I
Maple, red	I	R	I	R	R	S	R	R	I	I-S	R-I	I	I

a. S = susceptible, 60% or more defoliated in 90 days; I = intermediate, 60% or more defoliated at 1 year; R = resistant, less than 60% defoliated; - = no rating available.

6850

TABLE 9. PER CENT DEFOLIATION FROM AERIAL APPLICATIONS OF ORANGE AND BASIC DEFOLIANTS IN TROPICAL AND CONUS TEMPERATE FORESTS

Chemical and Location	Rate, lb./acre	Vol, gal/acre	% Defoliation 10-14 Days	1 Month	2 Months	3 Months	6 Months
ORANGE							
Hawaii	26	3	28	54	77	82	70
Hawaii	12	3	24	56	74	73	-a/
Puerto Rico	26	3	54	85	91	85	81
CONUS (5)b/	26	3	4	23	46	[illegible]	-
Diquat							
Hawaii	12	10	44	49	42	36	28
Puerto Rico	12	6	75	76	64	39	29
CONUS (3)	12	6	10	18	22	-	-
Paraquat							
Hawaii	9.4	10	40	44	40	35	34
Puerto Rico	12	6	67	79	79	71	67
CONUS (3)	12	6	7	17	29	-	-
DNBP							
Hawaii	not applied						
Puerto Rico	12	3	24	42	68	74	66
CONUS (1)	12	6	8	15	22	-	-
PCP							
Hawaii	12	3	53	54	50	41	-
Puerto Rico	12	3	29	57	59	52	58
CONUS (4)	12	3	4	16	24	-	-
BLUE							
Hawaii	12	6	52	57	53	47	-
Puerto Rico	12	6	61	70	73	57	43
CONUS (3)	12	6	9	30	39	-	-
AP-20							
Hawaii	12	6	36	40	42	40	-
Puerto Rico	12	6	22	34	43	36	31
CONUS (1)	12	6	2	16	20	-	-

a. Data unavailable.
b. Number in parentheses represents number of tests.

6851

All the desiccants and ORANGE gave a significantly higher degree of defoliation at the two tropical locations than in the temperate forests of the CONUS tests. The base line of 60% considered as minimum effective defoliation was not attained by any of the desiccants in Hawaii. In Puerto Rico, effective ratings were obtained for 2- to 4-month periods with diquat, paraquat, DNBP, and BLUE. ORANGE applied at 26 lb. per acre gave effective defoliation at both locations for at least 4 to 6 months starting 30 to 60 days after treatment. At the CONUS locations, ORANGE treatments rated effective at 1 year, but comparable evaluations at 3 and 6 months were not made.

1. Puerto Rico

Aerial spray treatments at the Puerto Rico site and their periods of effective defoliation are given in Table 10. Maximum per cent of defoliation was obtained with ORANGE and an ORANGE-picloram ester combination at 2 months after spray application. Paraquat appeared to be the most effective desiccant tested with a maximum defoliation of 79% at 1 to 2 months and a period of effective defoliation of from 2 weeks to 8 months. AP-20 tested singly at 12 lb. per acre did not give effective defoliation but most species showed rapid desiccation. BLUE was intermediate in performance with an effective period of defoliation ranging from 2 to 6 months. Of the systemic herbicides and combinations tested, all treatments involving ORANGE or picloram gave effective defoliation for up to 8 months or more.

More comprehensive data on the defoliation and desiccation responses of guava are given in Table 11 based on small plot studies using a telescoping pole sprayer. Guava is fairly resistant to herbicides and may be used to predict responses of other tropical and subtropical species.

Maximum defoliation of guava occurred at the 1-week interval from treatments with BLUE and AP-20. These materials and DNBP also gave nearly complete defoliation/desiccation in the same period. A maximum defoliation + desiccation of 95% was obtained for the DNBP + ORANGE combination. By 1 month many of the desiccants and herbicide combinations had caused effective defoliation and marked desiccation injury. Noteworthy treatments included paraquat + picloram, DNBP + ORANGE, and picloram + 2,4-D or WHITE. All desiccants except MSMA gave effective defoliation at 1 month at the higher rates of application, but in all cases the period of effective defoliation did not extend beyond 3 months. BLUE was generally superior to the other desiccants tested.

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TABLE 10. MAXIMUM DEFOLIATION AND PERIOD OF EFFECTIVE DEFOLIATION FROM AERIAL APPLICATIONS OF DESICCANTS AND DEFOLIANTS AT LAS MARIAS, PUERTO RICO, 17 SEPTEMBER 1967

Chemical	Rate, lb./acre	Vol, gal/acre	Max. Defol. %	Max. Defol. Period, months	Period of Effective Defoliation, months
Diquat	12	6	76	1	0.25 to 2
Paraquat	12	6	79	1 to 2	0.5 to 8
PCP	12	3	59	2	1 to 2
PCP + propanil	6 + 6	3	42	2	none
DNBP	12	3	74	3	2 to 6
DNBP (M3260)	12	3	53	1 to 2	none
BLUE	12	6	73	1 to 2	0.5 to 2.5
BLUE + AP-20	6 + 6	6	53	2	none
BLUE + picloram K salt	12 + 6	10	85	3	1 to 8+
AP-20	12	6	43	2	none
AP-20 + picloram ester	12 + 6	10	79	2	1 to 8+
AP-20 + picloram K salt	12 + 6	6	69	2	2 to 6
ORANGE	26	3	91	2	1 to 8+
ORANGE + picloram ester	12 + 3	3	98	2	1 to 8+
Picloram ester	6	3	83	2	1 to 8+
Picloram K salt	6	3	83	3	1 to 8+

6853

TABLE 11. PER CENT DEFOLIATION AND PER CENT DEFOLIATION PLUS DESICCATION FROM POLE SPRAYER APPLICATIONS OF DESICCANTS AND HERBICIDE MIXTURES ON GUAVA AT MAYAGUEZ, PUERTO RICO

Chemical	Rate, lb./acre	No. of Tests	% Defoliation/% Defoliation + % Desiccation				
			1 Week	1 Month	3 Months	6 Months	1 Year
ORANGE	26	8	21/55	76/95	87	85	73
ORANGE + picloram ester (M3140)	12 + 3	8	25/41	73/96	84	91	67
Diquat	6	2	16/42	44/65	47	24	53
Diquat	12	6	16/74	71/81	55	45	30
Paraquat	6	2	14/33	64/68	43	20	-a/
Paraquat	12	9	20/49	67/72	50	44	64
Paraquat + picloram	6 + 6	1	1/16	94/100	98	96	83
PCP	12	2	7/54	75/84	32	23	-
PCP	24	2	4/34	59/64	40	16	-
DNBP	6	1	12/24	42/43	24	6	-
DNBP	12	5	28/75	63/78	44	46	-
DNBP + ORANGE	6 + 12	2	15/95	90/100	99	90	-
BLUE	6	3	24/68	73/76	44	33	35
BLUE	12	9	35/71	70/73	46	48	61
BLUE	24	2	31/92	87/94	64	35	-
BLUE + picloram K salt	12 + 6	9	23/79	76/90	88	81	51
MSMA	12	2	14/48	54/55	33	25	57
AP-20	6	2	22/43	51/78	23	26	-
AP-20	12	3	36/45	57/45	33	25	-
AP-20	24	4	33/85	77/82	43	23	59
AP-20 + picloram K salt	12 + 6	2	42/66	67/91	99	96	-
AP-20 + picloram K salt	24 + 6	3	6/49	54/65	55	57	28
2,4,5-T + HCA	6 + 6	3	0/7	53/92	64	61	66
2,4,5-T + HCA	12 + 12	1	0/4	83/96	90	85	49
Picloram K salt	3	3	6/13	34/53	67	74	-
Picloram K salt	6	8	12/28	59/82	82	83	34
Picloram ester	3	2	7/25	51/83	100	82	-
Picloram ester	6	3	17/50	56/84	100	100	-
Picloram + 2,4-D (WHITE)	1.5 + .6	1	0/1	90/99	95	88	70

a. Data unavailable.

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Combinations of ORANGE, picloram, or 2,4,5-T with desiccants generally resulted in long-term defoliation of guava. Paraquat + picloram, DNBP + ORANGE, ORANGE + picloram ester (M3140), picloram + 2,4-D (WHITE), and picloram ester at 6 lb. per acre were among the most effective defoliants for periods of 6 months to 1 year.

2. Hawaii

A complete report of the aerial field tests in tropical forests near the Kauai Branch Experiment Station of the University of Hawaii has been made by Suehisa et al.[9] Abstracts and summaries of species responses are presented here for comparison with the Puerto Rico and CONUS test data.

Defoliation ratings for the basic desiccants in the Hawaii tests are given in Table 9. Maximum defoliation of all desiccants except AP-20 occurred at 1 month after application. None of the desiccants applied singly gave an effective overall defoliation based on composite ratings of individual species. In contrast, ORANGE gave maximum defoliation at 2 to 3 months and the effective period of defoliation extended beyond the 6-month observation period.

Table 12 presents a summary of maximum defoliation data and periods of effective defoliation for desiccants and desiccant mixtures. As shown in Table 9, none of the desiccants tested in Hawaii gave 60% or more overall defoliation although endothall was briefly effective on the principal dominant, ohia-lehua. Combinations of BLUE with either diquat or PCP were superior to BLUE at equivalent total rates and gave a brief period of effective defoliation. The improved formulation of PCP with propanil effectively defoliated a majority of the species at the 6-week period. Combinations of diquat + picloram and HCA + 2,4,5-T also gave effective defoliation for 4- to 5-month periods.

As shown in Table 13, combinations of ORANGE with PCP, DNBP, or BLUE gave defoliation equivalent in maximum intensity and duration to that of ORANGE alone applied at 12 lb. per acre. Combination mixtures of ORANGE with AP-20 and endothall were minimally effective for short periods. None of the desiccants used in these mixtures was effective when applied alone.

Picloram ester applied singly at 3 and 6 lb. per acre gave highly effective defoliation starting 2 months after treatment and continuing through the 6-month observation period. M3140, a combination of ORANGE and picloram ester, was the most effective chemical tested in terms of maximum defoliation response and percentage of species affected. Other picloram combinations were effective defoliants but their maximum effect was delayed until 4 months after application.

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TABLE 12. MAXIMUM DEFOLIATION AND PERIOD OF EFFECTIVE DEFOLIATION FROM AERIAL APPLICATIONS OF DESICCANTS AND DESICCANT MIXTURES AT KAUAI EXPERIMENT STATION, HAWAII, 1967-1968.

Chemical	Rate, lb./acre	% Overall	Maximum Defoliation Period, months	Maximum Defoliation % on Ohia-Lehua	Effective Defoliation Period, months	Effective Defoliation % of Species
BLUE	12	57	1	45	none	55
BLUE + diquat	6 + 6	73	1	80	0.25 to 2	78
BLUE + PCP	6 + 6	63	1.5	60	1.5	50
BLUE + AP-20	6 + 6	57	2	55	none	50
PCP	12	54	1	43	none	none
PCP + propanil	6 + 6	71	1.5	90	1 to 4	75
	12 + 12	59	3	70	none	67
Paraquat	9.4	44	1	75	none	38
Paraquat + endothall	3 + 1	61	1	75	1 to 2	87
	1 + 3	61	2	60	1 to 2	57
Diquat	6	55	1	55	none	44
Diquat + picloram K salt	3 + 3	85	4	90	1 to 5	87
HCA + 2,4,5-T	6 + 6	73	5	40	3 to 5	75
	12 + 12	78	5	75	2 to 6	67

TABLE 13. MAXIMUM DEFOLIATION AND PERIOD OF EFFECTIVE DEFOLIATION FROM AERIAL APPLICATIONS OF DESICCANTS AND MIXTURES CONTAINING ORANGE AND/OR PICLORAM

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TABLE 13. MAXIMUM DEFOLIATION AND PERIOD OF EFFECTIVE DEFOLIATION FROM AERIAL APPLICATIONS OF DESICCANTS AND MIXTURES CONTAINING ORANGE AND/OR PICLORAM AT KAUAI EXPERIMENT STATION, HAWAII, 1967-1968

Chemical	Rate, lb./acre	Maximum Defoliation % Overall	Maximum Defoliation Period, months	Maximum Defoliation % on Ohia	Effective Defoliation Period, months	Effective Defoliation % of Species
ORANGE	12	74	1	75	1 to 4+	75
ORANGE	16	80	3	90	1.5 to 5	87
ORANGE	24	82	3	80	1.5 to 6+	87
ORANGE + PCP	12 + 12	73	2	75	1 to 4+	87
PCP	12	54	1	43	none	33
ORANGE + DNBP	12 + 7.5	86	2	80	1 to 4+	87
ORANGE + DNBP	8 + 12	86	4	85	1 to 4+	87
DNBP	12	---------- not applied ----------				
ORANGE + BLUE	12 + 6	79	2	80	1.5 to 4+	87
BLUE	12	57	1	45	none	55
ORANGE + endothall	8 + 2	65	1.5	65	1.5 to 3	57
Endothall	3	56	1	65	1 to 1.5	33
ORANGE + AP-20	12 + 6	64	1.5	80	1.5 to 2	57
AP-20	6	33	3	12	none	0
AP-20	12	42	2	27	none	22
ORANGE + picloram K salt	8 + 4	81	2	90	2 to 6+	87
ORANGE + picloram ester	12 + 3	90	4	95	2 to 4+	87
Picloram ester	3	86	4	100	2 to 6+	80
Picloram ester	6	87	2	100	2 to 6+	87
Picloram + 2,4-D (WHITE)	1.5 + 6	70	4	80	2 to 4	80
Picloram + 2,4-D (WHITE)	3 + 12	78	4	80	2 to 6+	80

6857

Comparative susceptibility and resistance of the Hawaii species to the basic desiccants, ORANGE, picloram, and WHITE, are indicated in Table 14. Christmasberry and melastoma were susceptible to most of the desiccants. Guava, lantana, and silveroak appeared to be intermediate in susceptibility. Most species except tree fern were readily defoliated by ORANGE, picloram, and WHITE. False staghornfern was rapidly desiccated by both desiccants and systemic herbicides but was killed only by herbicides or herbicide-desiccant mixtures. Ohia-lehua, the most important tree in the test site vegetation, was killed by ORANGE and WHITE but showed variable response to the desiccant group.

TABLE 14. SPECIES RESPONSE[a] TO SELECTED DESICCANTS AND HERBICIDES IN HAWAII TESTS

Chemical	% of Total Species Effectively Defoliated	Christmasberry	Guava	Guava, Strawberry	Java Plum	Lantana	Melastoma	Ohia-Lehua	Rhodomyrtus	Silveroak	Staghornfern, False
BLUE	45	S	I	R	R	I	I	R	R	I	S
Diquat	45 to 67	S	I	R	S-I	I	S	S-I	R	R	S
Paraquat	37	S	R	R	I	I	S	S-I	-	I	S
PCP	33	I	I	I	I	S	S	R	R	R	S
Endothall	33	-	I	-	-	I	I	I	-	-	S
AP-20	22	S	R	R	I	R	R	R	R	R	S
ORANGE	75 to 87	-	S	S	-	I	S	S	-	-	S
Picloram	80 to 87	-	S	S	-	S	S	-	-	-	S
WHITE	80	-	-	-	-	I	S	S	-	-	S
HCA + 2,4,5-T	75	S	I	S	S	I	S	R	-	S	S

a. S = susceptible, 60% or more defoliated for 6 months or more; I = intermediate, 60% or more defoliated for 2 months but recovery within 6 months; R = resistant, less than 60% defoliation; - = no rating available.

6858

IV. DISCUSSION

A synopsis of the characteristics and performance of the basic desiccants and herbicides evaluated in this program is given in Table 15. General comments on individual chemicals and mixtures follow.

A. ORANGE

ORANGE applied at 3 gal per acre (26 lb. per acre acid equivalent) was used as a standard for comparison of candidate defoliants. The defoliation from ORANGE at 60 days in the CONUS and Canada tests was below the 60% level accepted as minimally effective in this study. Desiccation injury was fairly rapid in temperate-zone vegetation at this rate of application. Under tropical conditions, effective defoliation occurred at 1 to 3 months after application; browning or desiccation injury was severe 1 to 2 weeks after treatment. The Puerto Rico test showed more rapid and severe defoliation with ORANGE than the comparable rate applied in Hawaii.

B. BLUE

BLUE was moderately rapid in both defoliation and desiccation response. At the CONUS locations, appreciable defoliation occurred 10 days after treatment; by 1 month defoliation with BLUE exceeded that of any desiccant tested. However, BLUE did not give effective defoliation at any temperate-zone site. Maximum defoliation occurred at rates of 10 lb. per acre at 1 or 2 months after application. In the tropical tests, BLUE gave effective or nearly effective defoliation with maximum values 1 to 2 months after treatment.

Mixtures of BLUE with other desiccants such as paraquat and AP-20 gave some improvement in defoliation responses. A formulated mixture of BLUE and ORANGE gave enhanced desiccation but did not improve the defoliation characteristics of ORANGE.

In comparison with other candidate desiccants, BLUE rates lowest in toxicity and handling hazards.

C. DIQUAT

Diquat was unsatisfactory as a defoliant and desiccant under temperate conditions; maximum defoliation ratings of 24% were obtained at 60 days. Under tropical conditions diquat was less effective in defoliation than BLUE but reached maximum values of 40 to 76% at the 30-day interval.

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TABLE 15. CHARACTERISTICS AND PERFORMANCE OF CANDIDATE DEFOLIANTS AND ORANGE

Characteristic	ORANGE	BLUE	Diquat	Paraquat	DNBP	PCP	HCA + 2,4,5-T	AP-20	Endothall	MSMA + 2,4-D/2,4,5-T
Defoliation										
Rapidity	Slow	Mod.	Mod.	Mod.	Mod.	Mod.	Slow	Mod.	Mod.	Slow
Duration	Long	Short	Short	Short	Short	Short	Long	Short	Short	Mod.
Desiccation										
Rapidity	Slow	Mod.	Rapid	Rapid	Rapid	Mod.	Slow	Rapid	Rapid	Mod.
Rating	Fair	Good	Good	Good	Exc.	Good-Fair	Fair	Exc.	Good	Good
Effective Rate, lb./acre	26	15	12	12	24	- a/	6 + 6	-	-	20 + 5/5
Volume, gal/acre	3	6	6	6	6	-	6	-	-	10
Toxicity	Low	Low	Mod.	Mod.-High	High	Mod.-High	Low	Mod.	Mod.	Low
Hazard in handling	Low	Low	Mod.	Mod.	High	Mod.	Low	Mod.	Mod.	Low
Est. cost at effective rate	$24	$18	$117	$138	$15-20	-	$19	-	-	$55

a. Not applicable.

6860

Mixtures of diquat with BLUE did not enhance defoliation in either temperate or tropical sites. Improved defoliation was obtained by the addition of picloram ester in the Hawaiian test.

Diquat presents a moderate hazard in handling due to its skin-irritation properties. Cost at effective rates is relatively high.

D. PARAQUAT

Under temperate-zone conditions, paraquat was generally ineffective as a defoliant and desiccant at rates of 6 to 12 lb. per acre. The CONUS tests with paraquat failed to show any long-term defoliation effect but in the Canadian tests the hardwood or deciduous tree components showed a defoliation rating of 82% at 1 year after treatment. In the Puerto Rico tests paraquat was the most effective defoliant of the desiccants tested with a maximum rating of 79% attained in 30 days at 12 lb. per acre. However, in the single trial in Hawaii, paraquat was not an effective defoliant.

Mixtures of paraquat with picloram showed a significant enhancement in long-term defoliation attributable to the picloram component. A mixture containing 6 lb. per acre of paraquat and 4 lb. per acre of picloram gave the maximum defoliation of any CONUS test treatment at 1 year, but effective defoliation had not been attained by 60 days. This mixture was highly effective on guava in Puerto Rico but was not evaluated in the aerial tests in Puerto Rico or Hawaii.

Paraquat is somewhat more toxic than diquat in oral toxicity and skin irritation and presents some hazard in handling.

E. DINITROBUTYLPHENOL

DNBP was one of the most rapid and active desiccants tested but it was not an effective defoliant. In the CONUS tests, appreciable defoliation did not occur until 30 days after treatment. Aerial tests in Puerto Rico showed DNBP to be less effective in defoliation of tropical forest than BLUE, paraquat, or diquat. It was not included in the Hawaii test program.

M3260, the improved formulation of DNBP, gave better defoliation in the CONUS tests than in the tropical trial at Puerto Rico; the minimum effective level was attained in 60 days in late-season applications.

In CONUS tests the addition of DNBP to ORANGE induced more rapid desiccation than ORANGE but no improvement in defoliation. Hawaii tests of this mixture gave similar defoliation characteristics to that of ORANGE alone. In Puerto Rico, the combination of DNBP + ORANGE at 6 + 12 lb. per acre was one of the most effective defoliants on guava, giving 90% defoliation in 30 days.

6861

DNBP is high in toxicity and hazards for handling. The chemical is a strong and persistent yellow dye rapidly absorbed by the skin, causing blistering and irritation. The toxicity and handling hazards of DNBP should preclude its further consideration as a defoliant. Mixtures with ORANGE, however, offer possibilities for rapid marking of target areas and subsequent long-term defoliation.

F. PENTACHLOROPHENOL

Commercial formulations of PCP did not give an effective level of defoliation in either temperate or tropical area tests. However, significant desiccation occurred within 10 days after treatment. In CONUS tests the improved formulations of PCP failed to give effective defoliation within 60 days after application. Under tropical conditions in Hawaii, the combination of PCP and propanil (6 + 6 lb. per acre) gave minimally effective defoliation. Combinations of PCP with ORANGE were not effective defoliants in CONUS tests and showed no advantage over the standard ORANGE treatment in Hawaii trials.

Toxicity and handling problems with PCP are moderate in scope. The chemical is inexpensive but generally inferior in defoliant characteristics to other materials.

G. HEXACHLOROACETONE

HCA applied singly at rates up to 135 lb. per acre gave no defoliation activity in CONUS tests not reported in the tabular data. Combinations of HCA and 2,4,5-T were evaluated in comparison with ORANGE on the basis of reported synergistic effects of this combination on the defoliant properties of 2,4,5-T. In the CONUS tests, effective defoliation was obtained at 60 days with a 6 + 6 lb. per acre rate of HCA with 2,4,5-T as well as with similar rate combinations with 2,4-D and silvex. In Hawaii the combination of HCA and 2,4,5-T gave delayed but effective defoliation.

In overall defoliation performance, HCA mixtures have no advantage over ORANGE or other candidates.

H. AP-20

At the time of this test program, AP-20 was in early commercial development as a cotton defoliant and was potentially available in quantity production. In the temperate-zone tests at rates of 4 to 12 lb. per acre, AP-20 gave rapid desiccation. The effective levels of defoliation attained with this compound at 60 days are questionable because of the late season of application. Mixtures with ORANGE gave no improvement in defoliation characteristics although rapid desiccation occurred.

6862

In the tropical tests conducted at 12 lb. per acre, AP-20 was not an effective defoliant. Combinations of AP-20 with picloram ester provided no advantage in defoliation.

The compound was very difficult to handle because of its skin-blistering properties.

I. ENDOTHALL

Limited comparisons of endothall and mixtures with paraquat and ORANGE at temperate and tropical locations showed this chemical to give rapid desiccation but it was unsatisfactory as a defoliant. Only minimally effective defoliation was obtained in the Hawaii test with a mixture of ORANGE and endothall.

J. MONOSODIUM METHANEARSONATE

MSMA was tested singly only on guava at the Puerto Rico location, where it failed to give effective defoliation. The combination of MSMA + 2,4-D + 2,4,5-T proved to be unsatisfactory as a defoliant in the initial CONUS tests of basic defoliants.

Some difficulty was experienced with precipitate in the spray mixtures used in these tests.

K. SULFONYL FLUORIDES

Three sulfonyl fluoride formulations (40856, 41256, and 41414) were evaluated only in the late-season CONUS test. The materials were applied singly at 3 lb. per acre and in combinations with ORANGE at 18 lb. per acre (Table 4). Rapid desiccation occurred with both single and combination treatments. The mixtures with ORANGE gave effective defoliation at 60 days and nearly complete desiccation of the residual foliage.

No data are available on the performance of these chemicals under tropical conditions.

Popoff et al.[10] have reported on the chemical characteristics and desiccant activity of this group of compounds.

L. COMBINATIONS OF DESICCANTS WITH ORANGE

In CONUS tests, mixtures of ORANGE with AP-20, endothall, and the three sulfonyl fluoride formulations gave rapid desiccation and effective defoliation at 60 days. Long-term (1 year) evaluations of these mixtures, however, showed markedly reduced defoliation by comparison with the standard ORANGE treatments.

6863

In Hawaii, mixtures of ORANGE at 8 to 12 lb. per acre with PCP, BLUE, endothall, and AP-20 improved the defoliation characteristics of the desiccants for periods of 4 to 6 months.

In general, the addition of a desiccant to ORANGE caused more rapid desiccation and foliage browning but did not cause more rapid defoliation. The long-term defoliation from these mixtures was less effective than that of ORANGE applied singly.

M. PICLORAM AND HERBICIDE COMBINATIONS

Picloram is a highly active systemic herbicide, characteristically slower in defoliant response than ORANGE, and exhibiting a broad spectrum of phytotoxic activity. Maximum defoliation response is attained at 2 to 4 months after treatment under tropical conditions.

Combinations of picloram with desiccants tended to combine their rapid desiccant action with the long-term phytotoxicity of picloram. In CONUS tests, the most effective defoliant was a mixture of picloram as potassium salt with paraquat. In the Canadian test a mixture of picloram + diquat (3 + 3 lb. per acre) gave complete defoliation and kill of conifers and hardwoods at 1 year. In Puerto Rico tests on guava, picloram + paraquat at 6 + 6 lb. per acre gave the most complete (94% at 1 month) and rapid defoliation of any treatment. Both picloram and picloram-desiccant combinations were highly effective defoliants but slow in action in the Hawaii tests.

Agent WHITE, a mixture of 2,4-D and picloram, was one of the more effective long-term defoliants in the CONUS, Canadian, and tropical area tests. Under tropical conditions, maximum defoliation was not attained until 3 to 4 months after application.

The combination of picloram ester and ORANGE designated as M3140 was the most effective chemical in the Puerto Rico and Hawaii aerial tests. The effective level of defoliation was attained in 1 to 2 months with maximum levels at 4 to 6 months. Direct comparisons of this formulation with desiccant and herbicide/desiccant mixtures were not included in the CONUS or Canada tests.

6864

V. SUMMARY

A comprehensive field evaluation of commercially available desiccants, improved formulations, and mixtures of desiccants and herbicides was conducted by personnel of the Plant Sciences Laboratories in the search for an improved rapid-acting defoliant. An in-house program of greenhouse screening and formulation research provided 94 candidate agents and mixtures for preliminary evaluation in small plot tests conducted with cherrypicker or high-boom mobile spray equipment in Florida and Arkansas.

Aerial applications were made by in-house personnel with commercial helicopter equipment on duplicate 3-acre plots in forested areas in Florida, Georgia, and Arkansas (CONUS tests) and in New Brunswick, Canada. Evaluations were made of: (i) basic commercially available desiccants and the standard defoliant ORANGE; (ii) improved formulations and mixtures of three basic desiccants, DNBP, PCP, and HCA, supplied under industry contract; and (iii) combinations or mixtures of desiccants and/or herbicides for improved long-term defoliation. Concurrent OCONUS aerial applications and field tests were conducted by the U.S. Department of Agriculture in Puerto Rico and the University of Hawaii in Kauai, Hawaii, for evaluation of the three groups of candidate defoliants on tropical forest vegetation. Evaluations of defoliation and desiccation responses were made at 1-, 5-, 10-, 30-, and 60-day intervals and long-term defoliation at 1 year in the CONUS and Canada tests; in the OCONUS tests comparable evaluations were made at monthly intervals for periods of 4 to 12 months. Effective defoliation was judged to be 60% or more of the total vegetation canopy.

No candidate chemical gave effective defoliation within 10 days after application. At 30 days, defoliation from applications of the commercially available desiccants including BLUE, diquat, paraquat, DNBP, and PCP was equal or superior to that from the standard ORANGE applied at 3 gal per acre. At 10 to 14 days after treatment, BLUE gave a greater degree of defoliation than most desiccants.

DNBP, diquat, paraquat, AP-20, and endothall gave rapid browning and severe desiccation of sprayed foliage within 1 to 5 days. Improved formulations of DNBP and PCP from industry contracts gave increased desiccation injury but little improvement in defoliant characteristics.

Mixtures of ORANGE and desiccants such as BLUE, DNBP, PCP, and AP-20 gave more rapid desiccation but did not improve the defoliation characteristics of ORANGE. Adverse long-term effects on defoliation were noted in some mixtures in the CONUS and Canada tests, but not under tropical conditions.

Picloram + paraquat and picloram + 2,4-D (WHITE) were effective long-term defoliants in both tropical and temperate sites. M3140, a combination of picloram and ORANGE tested only at the tropical locations, gave the best defoliation of all compounds evaluated.

6865

Tropical species showed more rapid and greater defoliation response to most desiccants and herbicide mixtures than temperate-zone species. At the tropical sites, BLUE at 12 lb. per acre was slightly superior to other desiccants in defoliation. Paraquat at 12 lb. per acre gave a longer period of effective defoliation than other desiccants.

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APPENDIX A

CHEMICAL NAME, SOURCE, AND FORMULATION CHARACTERISTICS OF CHEMICALS USED IN TEST PROGRAM

A. BASIC DESICCANTS

1. BLUE

Mixture of sodium cacodylate and cacodylic acid (or hydroxydimethylarsine oxide)

Phytar 560G, Ansul Company

3.1 lb./gal of active ingredient

2. Diquat

6,7-dihydrodipyrido[1,2-a:2',1'-c]pyrazinediium ion

Ortho Diquat, Chevron Chemical Company

2 lb./gal of cation

3. Paraquat

1,1'-dimethyl-4,4'-bipyridinium ion

Ortho Paraquat, Chevron Chemical Company

2 lb./gal of cation

4. Dinitrobutylphenol (DNBP or dinoseb)

2-sec-butyl-4,6-dinitrophenol

Dow General, Dow Chemical Company

5 lb./gal of active ingredient

5. Pentachlorophenol (PCP)

pentachlorophenol

Timbertox, Monsanto Company

4 lb./gal of active ingredient

6. Hexachloroacetone (HCA)

1,1,1,3,3,3-hexachloro-2-propanone

Allied Chemical Corporation

HCA 95% oil concentrate, containing 14.4 lb./gal

HCA + 2,4,5-T, containing 2 lb./gal HCA + 2 lb./gal of 2,4,5-T ester

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7. Monosodium methanearsonate (MSMA)

monosodium methanearsonate

Ansul Company

MSMA + 2,4-D + 2,4,5-T, containing 2 lb./gal MSMA + 0.5 lb./gal each of 2,4-D + 2,4,5-T amine salts

8. AP-20

cis-2,3,5,5,5-pentachloro-4-keto-pentenoic acid

AP-20-WD-1, Air Products and Chemicals Inc.

3 lb./gal of active ingredient

9. Endothall

7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid

DES-I-CATE, Pennwalt Corporation

0.52 lb./gal of endothall acid

B. IMPROVED DESICCANTS

1. Hexachloroacetone (HCA) - Allied Chemical Corporation

HCA + 2,4-D, containing 1 lb./gal of each

HCA + linuron, containing 1 lb./gal of each

HCA + silvex, containing 1 lb./gal of each

2. Dinitrobutylphenol (DNBP or dinoseb) - Dow Chemical Company

M-3256, containing 1.2 lb./gal of DNBP with surfactant M-3253

M-3260, containing 1.2 lb./gal of DNBP with Chlorothene and dodecylbenzenesulfonic acid

M-3261, containing 1.2 lb./gal of DNBP with surfactant M-3254

3. Pentachlorophenol (PCP) - Monsanto Company

PCP, 6 lb./gal formulation in diacetone alcohol

PCP, 4 lb./gal formulation plus p-nitrophenol, 1 lb./gal in diacetone alcohol

PCP, 4 lb./gal formulation plus propanil in a 1:1 mixture of diacetone alcohol and mesityl oxide

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4. Benzenesulfonyl fluorides - Prepared by Cyclo Chemical Corporation based on synthesis procedures by Pennwalt Corporation

FD 40845, 3-chloro-4-hydroxybenzenesulfonyl fluoride

FD 41414, 3,5-dichloro-4-hydroxybenzenesulfonyl fluoride

FD 41256, 3,5-dichloro-2-hydroxybenzenesulfonyl fluoride

C. SYSTEMIC HERBICIDES

1. ORANGE

50:50 mixture of technical grade n-butyl esters of (2,4-dichlorophenoxy)acetic and (2,4,5-trichlorophenoxy)acetic acids

Available from Monsanto Company, Dow Chemical Company, and other basic producers of 2,4-D and 2,4,5-T

Mixture contains 8.6 lb./gal of acid equivalent

2. Picloram or Tordon

4-amino-3,5,6-trichloropicolinic acid

Dow Chemical Company

Tordon 22K containing 2 lb./gal of K salt

Tordon 101 containing 0.54 lb./gal of picloram and 2.0 lb./gal of 2,4-D as triisopropanolamine salts

M-3142 containing 4 lb./gal of isooctyl ester of picloram

M-3140 containing 1 lb./gal of picloram ester, 4.3 lb./gal of ORANGE or n-butyl esters of 2,4-D/2,4,5-T

3. 2,4,5-T

(2,4,5-trichlorophenoxy)acetic acid

Allied Chemical Corporation formulation with HCA containing 1 or 2 lb./gal of ethylhexyl ester of 2,4,5-T

D. MISCELLANEOUS HERBICIDES USED IN MIXTURES

1. Propanil

3',4'-dichloropropionanilide

2. p-Nitrophenol

para-nitrophenol

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3. Linuron

3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea

4. Silvex

2-(2,4,5-trichlorophenoxy)propionic acid

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APPENDIX B

DESCRIPTION OF TEST SITES

A. CONUS TESTS

1. Florida

Location: Apalachicola National Forest, near Sopchoppy, Wakulla County, Florida

Climate: Subtropical, humid, moderate precipitation

Soils:* Spodosol; sandy in flat, poorly drained topography

Vegetation Type:* Southern mixed forest; ridge site in river swamp forest with evergreen oaks, magnolia, and spruce pine dominant. Common and botanical names of principal species are given in Appendix C.

2. Georgia

Location: Fort Gordon, near Augusta, Georgia

Climate: Warm temperate, humid, moderate rainfall

Soils: Entisol; deep, well-drained sands in rolling topography

Vegetation Type: Oak-hickory-pine forest; sand hill site with longleaf pine, loblolly pine, and turkey oak predominant. See Appendix C for names of principal plant species.

3. Arkansas (I, II and III)

Location: Fort Chaffee, near Fort Smith, Arkansas

Climate: Temperate continental with moderate rainfall

Soils: Ultisol; fine sandy loam in rolling topography

Vegetation Type: Oak-hickory forest with post, blackjack, and southern red oak and water oak present. See Appendix C for names of principal plant species.

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* Classification of soils and vegetation is based principally on U.S. Geological Survey National Atlas Sheets 86, 89, and 90, on Vegetation and Soils, 1967-69.

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B. CANADA

Location: Base Gagetown near Fredericton, New Brunswick

Climate: Cool temperate, low to moderate precipitation

Soils: Spodosol; poorly drained sandy clay with rolling ridge and swamp topography

Vegetation Type: Northern hardwoods-spruce forest; grey birch, red maple, white spruce, and balsam fir dominant. See Appendix D for names of principal plant species.

C. PUERTO RICO

Location: Las Marias, northeast of Mayaguez, Puerto Rico

Climate: Tropical, humid, with 85 inches of annual precipitation

Soils: Oxisol or humic latosol; volcanic silty clays, steep slopes

Vegetation Type: Lower cordillera forest; Guarea, Erythrina, Cecropia, Didymopanax, and Inga dominant. See Appendix E for names of principal plant species.

D. HAWAII

Location: Kauai Branch Station, Hawaii Agriculture Experiment Station, near Kapaa, Kauai, Hawaii

Climate: Tropical, humid, 80 to 120 inches precipitation

Soils: Oxisol or humic ferruginous latosol, silty clay, steep ridges and deep valleys

Vegetation: Ohia-lehua forest; ohia-lehua, guava, java plum, and false staghornfern dominant. See Appendix F for names of principal plant species.

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APPENDIX C

PRINCIPAL WOODY PLANTS IN AERIAL APPLICATION TESTS OF DESICCANTS AND HERBICIDES AT CONUS LOCATIONS

Common Name	Botanical Name	Test Location: Fla.	Ga.	Arkansas: I	II	III
Conifers						
Pine, loblolly	*Pinus taeda* L.	-	X	-	-	-
Pine, longleaf	*Pinus palustris* Mill.	-	X	-	-	-
Pine, spruce	*Pinus glabra* Walt.	X	-	-	-	-
Broadleaf Evergreens						
Waxberry, southern	*Myrica cerifera* L.	X	-	-	-	-
Holly, American	*Ilex opaca* Ait.	X	-	-	-	-
Magnolia, southern	*Magnolia grandiflora* L.	X	-	-	-	-
Oak, bluejack	*Quercus incana* Bartr.	-	X	-	-	-
Oak, laurel	*Quercus laurifolia* Michx.	X	-	-	-	-
Oak, water	*Quercus nigra* L.	-	X	-	X	X
Sparkleberry	*Vaccinium arboreum* Marsh.	-	X	-	-	-
Sweetbay	*Magnolia virginiana* L.	X	-	-	-	-
Deciduous						
Ash, green	*Fraxinus pennsylvanica* Marsh.	X	-	-	-	-
Ash, white	*Fraxinus americana* L.	-	-	X	X	X
Blackgum	*Nyssa sylvatica* Marsh.	X	X	-	-	X
Dogwood, flowering	*Cornus florida* L.	-	X	-	X	X
Dogwood, stiffcornel	*Cornus foemina* Mill.	X	-	-	-	-
Elm, American	*Ulmus americana* L.	-	-	-	-	X
Elm, winged	*Ulmus alata* Michx.	-	-	X	X	X
Hackberry	*Celtis occidentalis* L.	-	-	-	-	X
Hawthorn	*Crataegus* sp.	-	X	X	X	X
Hickory, bitternut	*Carya cordiformis* (Wangenh.) K. Koch	-	-	X	X	X
Hickory, mockernut	*Carya tomentosa* Nutt.	X	-	-	-	-
Hickory, pignut	*Carya glabra* (Mill.) Sweet	-	X	-	-	-
Hophornbeam, eastern	*Ostrya virginiana* (Mill.) K. Koch	X	-	-	-	X
Hornbeam, American	*Carpinus caroliniana* Walt.	X	-	-	-	-
Locust, honey	*Gleditsia triacanthos* L.	-	-	X	-	X
Maple, red	*Acer rubrum* L.	X	-	-	X	X
Mulberry, red	*Morus rubra* L.	-	-	X	X	X
Oak, black	*Quercus velutina* Lam.	-	-	X	X	X
Oak, blackjack	*Quercus marilandica* Muenchh.	-	-	X	X	X
Oak, post	*Quercus stellata* Wangenh.	-	-	X	X	X
Oak, sand post	*Quercus stellata* var. *margaretta* (Ashe) Sarg.	-	X	-	-	-
Oak, southern red	*Quercus falcata* Michx.	-	X	X	X	X
Oak, swamp chestnut	*Quercus michauxii* Nutt.	X	-	-	-	-
Oak, turkey	*Quercus laevis* Walt.	-	X	-	-	-
Osage orange	*Maclura pomifera* (Raf.) Schneid.	-	-	X	-	-
Persimmon	*Diospyros virginiana* L.	-	X	X	X	X
Redbud	*Cercis canadensis* L.	-	-	-	-	X
Sweetgum	*Liquidambar styraciflua* L.	X	X	-	X	X
Sumac, shining	*Rhus copallinum* L.	-	X	X	X	X
Sycamore	*Platanus occidentalis* L.	-	-	-	-	X

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APPENDIX D

PRINCIPAL WOODY PLANTS IN AERIAL APPLICATION TEST OF DESICCANTS AND HERBICIDES AT BASE GAGETOWN, NEW BRUNSWICK, CANADA

Common Name	Botanical Name
Conifers	
Fir, balsam	Abies balsamea (L.) Mill.
Larch, American	Larix laricina (DuRoi) K. Koch
Pine, white	Pinus strobus L.
Spruce, white	Picea glauca (Moench) Voss
Hardwoods	
Alder, speckled	Alnus rugosa (DuRoi) Spreng.
Aspen, quaking	Populus tremuloides Michx.
Beech, American	Fagus grandifolia Enrh.
Birch, grey	Betula populifolia Marsh.
Maple, red	Acer rubrum L.
Maple, striped	Acer pensylvanicum L.
Viburnum	Viburnum sp.

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APPENDIX E

PRINCIPAL WOODY SPECIES IN AERIAL APPLICATION TEST IN MIXED SEMIEVERGREEN FOREST AT LAS MARIAS, PUERTO RICO

Common Name	Botanical Name
Aguacate	*Persea americana* Mill.
Algarrobo	*Hymenaea courbaril* L.
Bambu	*Bambusa vulgaris* Schrad.
Bucar	*Erythrina poeppigiana* (Walp.) O.F. Cook
Camasey	*Miconia prasina* (Sw.) DC.
Caoba	*Swietenia* sp.
China	*Citrus sinensis* Osbeck
Guaba	*Inga vera* Willd.
Guama	*Inga laurina* (Sw.) Willd.
Guara	*Cupania americana* L.
Guaraguao	*Guarea trichilioides* L.
Guineo	*Musa sapientum* L.
Helecho	*Cyathea arborea* (L.) J.E. Smith
Higuillo	*Piper aduncum* L.
Hoja menuda	*Eugenia rhombea* (Berg) Krug & Urban
Jaguey	*Ficus* sp.
Jobo	*Spondias mombin* L.
Laurel geo	*Ocotea leucoxylon* (Sw.) Mez
Mango	*Mangifera indica* L.
Moca	*Andira inermis* (W. Wright) H.B.K.
Moral	*Cordia sulcata* DC.
Palma real	*Roystonea borinquena* O.F. Cook
Palo de pollo	*Pterocarpus officinalis* Jacq.
Yagrumo hembra	*Cecropia peltata* L.
Yagrumo macho	*Didymopanax morototoni* (Aubl.) Decne. & Planch.

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APPENDIX F

PRINCIPAL WOODY PLANTS IN AERIAL APPLICATION TESTS OF DESICCANTS AND HERBICIDES IN TROPICAL FOREST NEAR KAUAI BRANCH STATION, KAUAI, HAWAII

Common Name	Botanical Name
Aiea	*Ilex anomala* Hook. & Arn.
Christmasberry	*Schinus terebinthifolius* Raddi
Fern, tree	*Cibotium* sp.
Guava	*Psidium guajava* L.
Guava, strawberry	*Psidium cattleianum* Sabine
Hala	*Pandanus odoratissimus* L.f.
Java plum	*Eugenia jambolana* Lam.
Kalia	*Elaeocarpus bifidus* Hook. & Arn.
Lantana	*Lantana camara* L.
Melastoma	*Melastoma malabathricum* L.
Ohia-Ha	*Eugenia sandwicensis* Gray
Ohia-Lehua	*Metrosideros polymorpha* Gaud.
Rhodomyrtus	*Rhodomyrtus tomentosa* Wight
Silveroak	*Grevillea robusta* A. Cunn.
Staghornfern, false	*Dicranopteris emarginata* (Brackenridge) Robinson
Waiwi	(See Guava, strawberry)

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13. ABSTRACT

Field evaluations were made of the rapidity and duration of defoliation of commercial desiccants, improved formulations, and desiccant-herbicide mixtures from aerial applications at temperate and tropical forest sites. Chemicals tested included ORANGE, BLUE, dinitrobutylphenol (DNBP), diquat, paraquat, pentachlorophenol (PCP), hexachloroacetone, and combinations of various chemicals with picloram, ORANGE, or 2,4,5-T.

No candidate chemical gave effective defoliation within 10 days after application, but BLUE was superior to most desiccants. At 30 days, defoliation from BLUE, diquat, paraquat, DNBP, and PCP was equal or superior to that from the standard ORANGE at 3 gallons per acre.

Mixtures of ORANGE and desiccants gave more rapid desiccation but no improvement in defoliation. Picloram + paraquat and WHITE or picloram + 2,4-D were effective long-term defoliants at both tropical and temperate sites. In general, tropical species showed better and more rapid defoliation than temperate species.

DD FORM 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Defoliation						
Desiccants						
Herbicides						
Trees						
Vegetation control						
ORANGE						
BLUE						
WHITE						
Dinitrobutylphenol						
Diquat						
Paraquat						
Pentachlorophenol						
AP-20						
Tordon						
Picloram						
Benzenesulfonyl fluorides						
2,4-D						
2,4,5-T						
Canada						
Puerto Rico						
Hawaii						

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US dumped Agent Orange in S Korea'
Tue Jul 12, 2011 4:44PM

South Koreans demonstrate in front of the US Embassy, demanding a probe into claims that the US army dumped the toxic chemical defoliant Agent Orange in the southeastern part of the country in the late 1970s.

An independent California-based research institute says the US army has dumped hundreds of barrels of toxic chemicals, including Agent Orange, in South Korea.

In an interview with Press TV, the Korea Policy Institute (KPI) Executive Director Christine Ahn elaborated on the revelation and indicated rising popular calls in South Korea for a probe into the reports.

"Three months ago in May, three US soldiers came out on local TV news in Arizona, confessing that they had buried almost hundreds of barrels of Agent Orange at Camp Caroll, which is a US military base in the southeastern part of South Korea," Ahn said.

"This is very explosive news and it sparked a major outcry from South Korean public for investigation into this," she added.

The KPI official said investigations earlier conducted by the United States showed signs of soil and water contamination in the area, referring to a 1992 report by Woodward-Clyde and a report by Samsung C&T in 2004.

"Many potential sources of soil and groundwater contamination still exist at the base and the presence of contaminated groundwater has been documented," the 1992 report said.

The Samsung report also confirmed soil samples from the base contained pesticides and dioxins -- a byproduct of Agent Orange.

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“Hazardous materials and waste, including solvents, petroleum oils and lubricants, pesticides, herbicides and other industrial chemicals have been used and stored onsite for over 40 years,” it said.

The findings, Ahn said, has raised concerns among the South Korean public about the hazards of the ongoing US military presence in the country.

She said South Koreans are now calling for a review of a security agreement between Seoul and Washington, under which the US soldiers cannot be held liable for the environmental contamination.

Agent Orange is a deadly herbicide used by the United States during the Vietnam War in the 1970s to strip trees of foliage and to deprive Vietnamese forces of cover and food.

The US military sprayed an estimated 10 million gallons of Agent Orange on forests and rice fields in Vietnam, where some three million people are said to have suffered the effects of wartime herbicides.

The US also used the carcinogenic chemical in Korea, along the de-militarized zone, to defoliate the forests and prevent North Koreans from crossing the border.

MRS/AKM

Related Stories:

- S Koreans protest US base pollution
- Seoul probes US Agent Orange site

HEADQUARTERS
UNITED STATES FORCES KOREA
APO SAN FRANCISCO 96301-0010

USFK Regulation
No. 700-17

7 May 1987

Logistics
USE OF HERBICIDES IN THE REPUBLIC OF KOREA

SUPPLEMENTATION. Issue of further supplements to this regulation by subordinate commands is prohibited unless prior approval is obtained from HQ USFK, ATTN: EAFE-E, APO SF 96301-0082.

INTERIM CHANGES. Interim changes to this regulation are not official unless they are authenticated by the Adjutant General. Users will destroy interim changes on their expiration dates unless sooner superseded or rescinded.

INTERNAL CONTROL SYSTEMS. This regulation is not subject to the requirements of AR 11-2. It does not contain internal control provisions.

1. PURPOSE. This regulation establishes policies and prescribes procedures for the control of herbicides used by USFK.

2. APPLICABILITY. This regulation is applicable to all component commands of USFK.

3. IMPACT ON NEW MANNING SYSTEM. This regulation does not contain information that affects the New Manning System.

4. REFERENCES.

a. DOD Directive 4150.7 (DOD Pest Management Program) is a required publication. Cited in paragraph 10e.

b. Related publications are listed below.

(1) AFR 91-21 (Pest Management Program).

(2) AFR 91-22/AR 40-574 (Aerial Dispersal of Pesticides).

(3) AR 200-1 (Environmental Protection and Enhancement).

(4) AR 385-32 (Protective Clothing and Equipment)

(5) AR 420-74 (Natural Resources--Land, Forest, and Wildlife Management).

(6) AR 420-76 (Pest Management).

(7) TM 5-629/NAVFAC MO-314/AFM 91-19 (Herbicide Manual).

*This regulation supersedes USFK Reg 700-17, 12 March 1984

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5. **EXPLANATION OF TERMS.** A herbicide is defined as a chemical compound that will kill or damage plants.

a. Based on physiological action, herbicides are grouped and described as--

(1) Contact herbicide. A herbicide that kills or inhibits plant growth primarily by contact with plant tissues.

(2) Plant growth regulator. A herbicide that kills or inhibits growth (depending on concentration) as a result of translocation of the herbicide chemical primarily through the root system to the plant cells (referred to also as "plant hormones").

(3) Defoliant. A herbicide that will cause a plant to prematurely shed its leaves.

(4) Desiccant. A herbicide that will cause the foliage of a plant to dry up.

b. Based on use, herbicides are grouped and described as--

(1) Selective or specific herbicide. A herbicide that in effective concentration will kill, damage, defoliate, desiccate, or inhibit the growth of some types of plants without significantly affecting other types of plants.

(2) Soil sterilants. A nonspecific herbicide that renders soil incapable of supporting plant growth.

6. **RESPONSIBILITIES.** Component commanders are responsible for the implementation of this regulation.

7. **HANDLING AND APPLICATION.** The dangers associated with the handling and application of herbicides demand establishment of strict controls for their use since nearly all herbicides are potentially dangerous. Injury to personnel or unnecessary damage to desirable vegetation and local crops adjacent to military installations can be prevented if herbicides are used properly and if recommended precautions are observed. Claims or adverse publicity resulting from the use of herbicides in the Republic of Korea negate the advantages of herbicides versus conventional brush and weed removal procedures.

8. **POTENTIAL HAZARDS.** A knowledge and appreciation of the factors that influence results in the use of herbicides are essential to the best control. The potential hazards that require special consideration in the use of herbicides are--

a. Poisoning of personnel. This hazard applies to persons who while mixing and applying the spray or spreading the dry product can be poisoned from swallowing the herbicides, from skin absorption, or from inhalation.

b. Inadvertent misuse. Security and control of herbicides are essential to prevent inadvertent use or misuse by persons not knowledgeable of the effects.

c. Drift hazards. These are greatest when herbicides that affect leaves of plants are used. Plants more than a mile downwind from the sprayed area may be affected.

d. Leaching. A process by which the herbicide is dissolved and diffused into the ground. If chemicals are readily absorbed by roots, plants whose roots extend under the treated area are likely to be injured.

e. Washing. A significant hazard on slopes, bare ground, and pavements. The herbicides may be carried by surface runoff to valuable plants downslope or contaminate streams or other bodies of water to the detriment of crops, fish, or other aquatic life.

9. STORAGE, ISSUE, AND HANDLING.

a. Request to procure or dispose of herbicides will be submitted to HQ USFK, ATTN: EAFE-E, APO SF 96301-0082.

b. Herbicides will be securely stored, and issues will be rigidly controlled. Disposal of herbicides will be accomplished only as directed by this headquarters. Sale or issue of herbicides to non-US Government activities or to non-DOD activities within the Republic of Korea is specifically prohibited without the approval of this headquarters.

c. Adequate individual safety precautions will be emphasized, and necessary protective devices shall be provided for all persons engaged in handling herbicides.

d. Records will be maintained in sufficient detail to provide the necessary information to permit evaluation of claims that may rise against the US Government.

10. POLICIES. Herbicides will not be used in the Republic of Korea except where plant growth control cannot be accomplished effectively by other means, and safe and controlled application of herbicides is ensured. Additionally, the following specific constraints apply to the use of herbicides in the Republic of Korea:

a. Herbicides will not be dispersed by aerial spraying.

b. To ensure that herbicide application will not impact land not under USFK control, herbicides will not be used by US Forces outside compounds controlled by US Forces except on areas approved in writing by HQ USFK and the Republic of Korea Government authority concerned. Request for exception will be submitted to HQ USFK, ATTN: EAFE-E, with maps and other data in sufficient detail for review.

c. Herbicides will not be applied in the demilitarized zone or south of the southern boundary when there is any possibility that drift of spray or runoff may carry any trace of the herbicides into the demilitarized zone.

d. Herbicide Agent ORANGE and any herbicide or other agricultural material containing the herbicide formulation 2-4-5 T or dinoseb will not be used in the Republic of Korea.

e. Herbicides shall be applied only under the direct supervision of certified personnel in accordance with DOD Directive 4150.7, paragraph F.

f. Initiate safety procedures for flushing and cleanup of dispensing equipment after the application of herbicides to prevent contamination of water used for irrigation purposes or water supplies used for consumption by domestic animals, wildlife, or aquatic life.

g. Additional specific precautions established by the US Environmental Protection Agency for the specific herbicide being used will be followed. Excess herbicides or contaminated containers will be disposed of in accordance with label directions.

h. Herbicides will not be applied in areas within a radius of 200 feet from any known underground well or surface water source.

The proponent of this regulation is the US Army Facilities Engineer Activity, Korea. Users are invited to send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) to the Commander, USFK, ATTN: EAFE-E, APO SF 96301-0082.

FOR THE COMMANDER:

H. L. OLSON
Major General, USA
Chief of Staff

OFFICIAL:

[redacted] b6

2LT, USA
Assistant Adjutant General

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A

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ACTIVITY, KOREA, ATTN: EAFE-E

USFK REGULATION 700-17

LOGISTICS (700)

Use of Herbicides in Korea

07 May 1987

UNCLASSIFIED

6888

*USFK Reg 700-17

HEADQUARTERS
UNITED STATES FORCES KOREA
APO SAN FRANCISCO 96301-0010

USFK Regulation
No. 700-17

7 May 1987

Logistics
USE OF HERBICIDES IN THE REPUBLIC OF KOREA

SUPPLEMENTATION. Issue of further supplements to this regulation by subordinate commands is prohibited unless prior approval is obtained from HQ USFK, ATTN: EAFE-E, APO SF 96301-0082.

INTERIM CHANGES. Interim changes to this regulation are not official unless they are authenticated by the Adjutant General. Users will destroy interim changes on their expiration dates unless sooner superseded or rescinded.

INTERNAL CONTROL SYSTEMS. This regulation is not subject to the requirements of AR 11-2. It does not contain internal control provisions.

1. **PURPOSE.** This regulation establishes policies and prescribes procedures for the control of herbicides used by USFK.

2. **APPLICABILITY.** This regulation is applicable to all component commands of USFK.

3. **IMPACT ON NEW MANNING SYSTEM.** This regulation does not contain information that affects the New Manning System.

4. **REFERENCES.**

a. DOD Directive 4150.7 (DOD Pest Management Program) is a required publication. Cited in paragraph 10e.

b. Related publications are listed below.

(1) AFR 91-21 (Pest Management Program).

(2) AFR 91-22/AR 40-574 (Aerial Dispersal of Pesticides).

(3) AR 200-1 (Environmental Protection and Enhancement).

(4) AR 385-32 (Protective Clothing and Equipment)

(5) AR 420-74 (Natural Resources--Land, Forest, and Wildlife Management).

(6) AR 420-76 (Pest Management).

(7) TM 5-629/NAVFAC MO-314/AFM 91-19 (Herbicide Manual).

*This regulation supersedes USFK Reg 700-17, 12 March 1984

6889

5. EXPLANATION OF TERMS. A herbicide is defined as a chemical compound that will kill or damage plants.

a. Based on physiological action, herbicides are grouped and described as--

(1) Contact herbicide. A herbicide that kills or inhibits plant growth primarily by contact with plant tissues.

(2) Plant growth regulator. A herbicide that kills or inhibits growth (depending on concentration) as a result of translocation of the herbicide chemical primarily through the root system to the plant cells (referred to also as "plant hormones").

(3) Defoliant. A herbicide that will cause a plant to prematurely shed its leaves.

(4) Desiccant. A herbicide that will cause the foliage of a plant to dry up.

b. Based on use, herbicides are grouped and described as--

(1) Selective or specific herbicide. A herbicide that in effective concentration will kill, damage, defoliate, desiccate, or inhibit the growth of some types of plants without significantly affecting other types of plants.

(2) Soil sterilants. A nonspecific herbicide that renders soil incapable of supporting plant growth.

6. RESPONSIBILITIES. Component commanders are responsible for the implementation of this regulation.

7. HANDLING AND APPLICATION. The dangers associated with the handling and application of herbicides demand establishment of strict controls for their use since nearly all herbicides are potentially dangerous. Injury to personnel or unnecessary damage to desirable vegetation and local crops adjacent to military installations can be prevented if herbicides are used properly and if recommended precautions are observed. Claims or adverse publicity resulting from the use of herbicides in the Republic of Korea negate the advantages of herbicides versus conventional brush and weed removal procedures.

8. POTENTIAL HAZARDS. A knowledge and appreciation of the factors that influence results in the use of herbicides are essential to the best control. The potential hazards that require special consideration in the use of herbicides are--

a. Poisoning of personnel. This hazard applies to persons who while mixing and applying the spray or spreading the dry product can be poisoned from swallowing the herbicides, from skin absorption, or from inhalation.

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b. Inadvertent misuse. Security and control of herbicides are essential to prevent inadvertent use or misuse by persons not knowledgeable of the effects.

c. Drift hazards. These are greatest when herbicides that affect leaves of plants are used. Plants more than a mile downwind from the sprayed area may be affected.

d. Leaching. A process by which the herbicide is dissolved and diffused into the ground. If chemicals are readily absorbed by roots, plants whose roots extend under the treated area are likely to be injured.

e. Washing. A significant hazard on slopes, bare ground, and pavements. The herbicides may be carried by surface runoff to valuable plants downslope or contaminate streams or other bodies of water to the detriment of crops, fish, or other aquatic life.

9. STORAGE, ISSUE, AND HANDLING.

a. Request to procure or dispose of herbicides will be submitted to HQ USFK, ATTN: EAFE-E, APO SF 96301-0082.

b. Herbicides will be securely stored, and issues will be rigidly controlled. Disposal of herbicides will be accomplished only as directed by this headquarters. Sale or issue of herbicides to non-US Government activities or to non-DOD activities within the Republic of Korea is specifically prohibited without the approval of this headquarters.

c. Adequate individual safety precautions will be emphasized, and necessary protective devices shall be provided for all persons engaged in handling herbicides.

d. Records will be maintained in sufficient detail to provide the necessary information to permit evaluation of claims that may rise against the US Government.

10. POLICIES. Herbicides will not be used in the Republic of Korea except where plant growth control cannot be accomplished effectively by other means, and safe and controlled application of herbicides is ensured. Additionally, the following specific constraints apply to the use of herbicides in the Republic of Korea:

a. Herbicides will not be dispersed by aerial spraying.

b. To ensure that herbicide application will not impact land not under USFK control, herbicides will not be used by US Forces outside compounds controlled by US Forces except on areas approved in writing by HQ USFK and the Republic of Korea Government authority concerned. Request for exception will be submitted to HQ USFK, ATTN: EAFE-E, with maps and other data in sufficient detail for review.

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c. Herbicides will not be applied in the demilitarized zone or south of the southern boundary when there is any possibility that drift of spray or runoff may carry any trace of the herbicides into the demilitarized zone.

d. Herbicide Agent ORANGE and any herbicide or other agricultural material containing the herbicide formulation 2-4-5 T or dinoseb will not be used in the Republic of Korea.

e. Herbicides shall be applied only under the direct supervision of certified personnel in accordance with DOD Directive 4150.7, paragraph F.

f. Initiate safety procedures for flushing and cleanup of dispensing equipment after the application of herbicides to prevent contamination of water used for irrigation purposes or water supplies used for consumption by domestic animals, wildlife, or aquatic life.

g. Additional specific precautions established by the US Environmental Protection Agency for the specific herbicide being used will be followed. Excess herbicides or contaminated containers will be disposed of in accordance with label directions.

h. Herbicides will not be applied in areas within a radius of 200 feet from any known underground well or surface water source.

> The proponent of this regulation is the US Army Facilities Engineer Activity, Korea. Users are invited to send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) to the Commander, USFK, ATTN: EAFE-E, APO SF 96301-0082.

FOR THE COMMANDER:

OFFICIAL:

[redacted] b6
2LT, USA
Assistant Adjutant General

H. L. OLSON
Major General, USA
Chief of Staff

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15 - US ARMY FACILITIES ENGINEER
ACTIVITY, KOREA, ATTN: EAFE-E

Historical Review of the 1968 Project to Spray Tactical Herbicides on the Korean DMZ

Prepared by

[redacted] Ph. D. and [redacted] MA
b6 b6
Professor of Environmental Toxicology and Principal Researcher, Respectively

Oak Ridge Institute for Science and Education

Oak Ridge Associated Universities

30 November 2011

For

The Eighth United States Army

Republic of South Korea

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
Managed by ORAU for DOE

[redacted] Consulting, Inc.
b6

6893

30 November 2011

David J. Conboy, Brigadier General, USA
Deputy Commanding General
Eighth United States Army
Yongsan Army Garrison
The Republic of South Korea

Dear BG Conboy,

Please find attached to this letter the Final Report on: **Historical Review of the 1968 Project to Spray Tactical Herbicides on the Korean DMZ**. The report is in fulfillment of a contract between Oak Ridge Institute for Science and Education and [redacted] Consulting, Inc.
b6

In July 2011, you tasked me with supporting the Eighth United States Army's evaluation of the allegations of improper use and burial of Agent Orange in Korea. After a thorough examination of the historical records, documents and reports found in the United States Archives in Washington, DC, the only use of Agents Orange and Blue in Korea occurred 15 May – 15 July 1968 on the Korean Demilitarized Zone (DMZ). The use of these two "tactical herbicides" was jointly approved by the Governments of the United States and of the Republic of South Korea, and with coordination of the United Nations Command. The actual application of the tactical herbicides was done professionally and with the upmost care by the First Republic of Korea Army (FROKA).

After a thorough review of the science, the prospect of any significant exposure and subsequent health impact from the spraying of the dilute Agent Orange or its associated dioxin contaminant on the DMZ to the soldiers of the FROKA or nearby residents seems unlikely in light of the environmental dissipation of the dioxin, it's extremely limited bioavailability, and the properties of the herbicides and circumstances of application that occurred.

It has been an honor to be of service to the Eighth United States Army.

Sincerely,

b6
[redacted] PhD
Professor of Environmental Toxicology

6894

DISCLAIMER

The views and opinions expressed in this Report on:

HISTORICAL REVIEW OF THE 1968 PROJECT TO SPRAY TACTICAL HERBICIDES ON THE KOREAN DMZ

Do not necessarily represent those of The Eighth United States Army, The United States Department of Defense, or any Department or Agency of the United States Government.

ACKNOWLEDGEMENT

The authors acknowledge the contractual arrangements through Oak Ridge Associated University's Oak Ridge Institute for Science and Education, and the financial support of the United States Army Environmental Command.

BRIEF BIOGRAPHY OF THE AUTHORS

For more than 40 years, Dr. [redacted] has been involved in issues surrounding the use of Agent Orange and other tactical herbicides in Vietnam. He completed his PhD in Herbicide Physiology and Environmental Toxicology at Kansas State University in 1968. In his 21 years with the USAF (obtaining the rank of Colonel), he was involved with the testing and evaluation of the equipment used in Operation RANCH HAND, Vietnam, and with the environmental and human health studies with the School of Aerospace Medicine and the Department of Veterans Affairs. He served as a Science Advisor on environmental issues including Agent Orange with the President's Office of Science and Technology Policy. He was the Director of the Department of Energy's Center for Risk Excellence. He was a Visiting Professor at the University of Oklahoma, 2001-2007, and is currently serving as the Senior Consultant on Agent Orange for the Office of the Deputy Under Secretary of Defense (Installations and Environment). He has more than 300 publications in the scientific literature, including five books on issues related to Agent Orange and/or dioxins and furans. He is currently the Co-Editor of the international journal *Environmental Science and Pollution Research*.

For the past ten years, [redacted] has been the Principal Researcher for [redacted] Consulting. He received his Bachelor of Arts in Political Science from DePaul University, Chicago (Magna Cum Laude, Phi Kappa Phi, and Pi Sigma Alpha). He received the Master of Arts in International Relations in 2010 through Webster University's Global Program having studied in Europe and China. He has provided support to the company in areas of public policy, technical issues, archival research, and the coordination of national and international projects.

HISTORICAL REVIEW OF THE 1968 PROJECT TO SPRAY TACTICAL HERBICIDES ON THE KOREAN DMZ

By

[redacted] Ph.D and [redacted] MA
b6 b6

TABLE OF CONTENTS

EXECUTIVE SUMMARY

In numerous domestic and international media reports throughout May and June 2011, allegations were made that the military defoliant Agent Orange had been buried in 1978 at Camp Carroll, a US military installation in South Korea. Moreover, some US veterans who had served in South Korea in the 1960s and 1970s claimed that Agent Orange had been routinely sprayed in South Korea. Accordingly, a critical review was conducted of the historical records in the US National Archives of the United States Air Force Office of the Judge Advocate General and of the Eighth US Army, South Korea. In addition supporting books and reports detailing the use of the tactical herbicides, including Agent Orange and Agent Blue, in the War in Vietnam were consulted and cited. These records and publications confirmed that the only use of Agents Orange and Blue in Korea occurred in May – July 1968 on the Korean Demilitarized Zone (DMZ). This report is intended to clarify what occurred in 1968, to explain why Agent Orange could not have been buried or sprayed in other locations in Korea, to describe the actual program on the DMZ, and to briefly review the supporting science.

Early in 1967, as part of a general review of the DMZ defenses, the United Nations Command, the United States Forces Korea, and the Korean Ministry of National Defense concurred that dense vegetation within the DMZ and contiguous areas provided cover for North Korean infiltration or raiding parties. The vegetation in these areas had grown unencumbered since the Armistice and was an important part of the DMZ defensive problem. In comprehensive research reports on the Vietnam War, it was noted that Korean Forces in Vietnam (1965 – 1971) had employed tactical herbicides, such as Agent Orange and Agent Blue, for the control of vegetation on base perimeters to maintain a clear "field of fire". The Korean Forces found that the use of such tactical herbicides to control the perimeter vegetation was extraordinarily effective in denying the enemy concealment and infiltration.

The decision, however, to use tactical herbicides in Korea on the DMZ required obtaining approval of the United States Government, the Republic of South Korea Government, and the United Nations Command. Numerous messages were dispatched during the period May through September 1967. Throughout September 1967, the US Secretary of State continued discussion of the program with the Republic of South Korea Government (ROK). These discussions provided the acceptance of the program by the ROK Prime Minister, and on 20 September 1967 both governments (ROK and US) granted permission for the use of both of the tactical herbicides to be sprayed in the area between the DMZ South tape and the

Civilian Control Line, a strip of land that would be roughly 320 meters wide and 240 kilometers long. On 20 January 1968, the United Nations Command, Military Armistice Commission, disclosed to North Korean counterparts that the UN Command may use military defoliants to clear underbrush from fields of fire in the DMZ and thereby reduce North Korean infiltration.

Based upon cables and messages found in the National Archives in Washington, The two tactical herbicides were acquired from the inventories in South Vietnam and shipped to the Port of Inchon. The inventory of Agent Orange and Agent Blue arrived at the Port of Inchon on 20 March 1968. On 10 April 1968 supplies of Agents Orange and Blue were on-hand in forward locations near the DMZ. Documents also confirmed that all of the herbicides were sprayed by the First Republic of Korea Army (FROKA) and that all of the herbicides were expended on the DMZ. A document also confirmed that the empty drums were the property of FROKA and were appropriately rinsed, capped and disposed.

The controversies surrounding Agent Orange in Southeast Asia resulted in significant restrictions for its use in late 1968, and all uses terminated in April 1970. A message from the Pacific Air Forces (PACAF), dated 13 October 1971 to all military units in Southeast Asia, directed that any remaining stocks of Agent Orange were to be consolidated and processed for removal to Johnston Island. There were no stocks identified from South Korea, thus confirming that there were no excess stocks remaining after application on the Korean DMZ, or for their use in 1969. In addition, US Department of Defense Directives dictated that US Army personnel or their contractors were not authorized to acquire or spray Agent Orange at US military installations.

The allegations about the burying or routine spraying of Agent Orange were not based on military directives or the facts found within the historical records; namely, there was never any Agent Orange sent to or buried at Camp Carroll, or sprayed elsewhere in South Korea except at the DMZ in 1968.

A brief review of the supporting science on the herbicides that comprised Agent Orange and its associated dioxin (TCDD) concluded that the prospect of any significant exposure and subsequent health impacts to TCDD from Agent Orange in the FROKA soldiers or nearby residents seems unlikely in light of the environmental dissipation of TCDD, its limited bioavailability, and the properties of the herbicides and circumstances of application that occurred.

INTRODUCTION

For almost four decades, controversy has surrounded the tactical use of herbicides, specifically "Agent Orange", in Southeast Asia by the United States Department of Defense (DoD). The breadth of the controversy has spanned the gamut from alleged military use of chemical weapons, to ecological damage and public health impacts, and to social and political concerns.[1] Most recently there was controversy over the use of Agents Orange and Blue in South Korea and the alleged subsequent disposal of the surplus inventories of the tactical herbicides on US military installations in South Korea. In May 2011, three US veterans told a Phoenix, Arizona television station that the Eighth United States Army (EUSA) had buried the defoliant Agent Orange at Camp Carroll, Korea in 1978.[2] As a result of their alleged actions to help bury large amounts of the chemical in a ditch on the installation, they claimed to have suffered health problems from their exposure to Agent Orange. Because of their claims, other US veterans and Korean citizens made new claims that Agent Orange was also buried or spilled at other US military installations and that it was sprayed near villages adjacent to the Korean Demilitarized Zone (DMZ) and elsewhere in Korea.[3, 4] The time span for these allegations was from 1963 through 1978. In December 2006, the US Department of Defense documented the history of the Department's programs for the testing, evaluation, and storage of tactical herbicides, including Agent Orange, other than their use in South Vietnam.[5] The only reported documented use of tactical herbicides in Korea occurred in May – July 1968 as part of a program to control vegetation on the Korean Demilitarized Zone and included Agents Orange and Blue.[6]

---

1. A. L. Young, *Agent Orange: A History of Its Use, Disposition, and Environmental Fate* (Prepared for the Office of the Under Secretary of Defense, Washington DC, June 2008). Available from the Armed Forces Pest Management Board, Literature Retrieval System (AFPMB), Accession No. 188312.
2. A. Rowland and Y.K Chang, *S. Korea probes allegations of buried chemicals at ex-U.S. base* (Stars and Stripes, May 25, 2011).
3. N. Jong-young, *Allegations expand to civilian mobilization for DMZ dump.* (Yonhap News, May 26, 2011).
4. C. Ahn and G. Kirk, *Agent Orange in Korea* (FPIF, Institute for Policy Studies, Washington, DC, July 7, 2011).
5. A. L. Young, *The History of the US Department of Defense Programs for the Testing, Evaluation, and Storage of Tactical Herbicides* (Prepared for the Office of the Under Secretary of Defense, Washington DC, December 2006). AFPMB LRS, Accession No. 182581.
6. [redacted] *Final Report, Vegetation Control Plan CY 68* (Prepared for the Combat Developments b6 Command, Chemical-Biological-Radiological Agency, Fort McClellan, Alabama, June 2, 1969). AFPMB LRS, Accession No. 189788.

The purpose of this Report is to: (1) document the history of the Korean military's use of tactical herbicides in Vietnam and how this provided the justification for their use on the Korean DMZ; (2) document the political, scientific and logistical processes used in selecting, obtaining, and transporting the tactical herbicides for use on the DMZ in 1968; (3) document the actual application of the tactical herbicides on the Korean DMZ; (4) document that Agent Orange could not have been buried or sprayed in other locations in Korea; and (5) review the science that concluded that the use of the tactical herbicides on the Korean DMZ resulted in minimal environmental and human impacts.

THE HISTORY OF THE KOREAN MILITARY'S USE OF TACTICAL HERBICIDES

The history of Agent Orange and Korean veterans does not begin with the use of Korean soldiers to spray Agent Orange and Agent Blue on the Korean DMZ, but rather it begins with the use of tactical herbicides as tools to prevent infiltration of Korean base perimeters in South Vietnam during the Vietnam War. More than 312,800 Korean combat veterans were stationed in South Vietnam's II Corps in the seven years from their arrival in 1965 to their departure in 1971. The motto of the men who served from Korea in South Vietnam was "7 Years for Peace and Construction" and the accomplishments of the Korean forces in Vietnam were a great sense of pride to the Korean people. [7] It was of great political significance for the Korean government to be able to send its army as an independent force. The major Korean Forces consisted of the Republic of Korea (ROK) Capital Division, ROK 9th Division, and the ROK 2nd Marine Brigade [8]. From their first deployment in II Corps (from Qui Nhon to Phan Rang) until their departure, a major concern was securing the base perimeters so as to maintain a clear field of fire. Of the many methods used to do that task by the Allied forces (including the Korean forces) was the use of the tactical herbicides to control the perimeter vegetation. [9] According to a comprehensive research report on the Vietnam War, Korean Units in Vietnam received tactical herbicides such as Agent Orange, Agent White and Agent Blue from the US Chemical Corps, but the Korean military did not permit the US Chemical Corps to conduct the spray operations. That was the duty and responsibility of the Korean forces within their tactical area of responsibility, and they employed their own ground and helicopter equipment to do the applications. [10]

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7. S. R. Larson and J. L. Collins, Jr., *The Republic of Korea*, Chapter VI: IN: *Vietnam Studies: Allied Participation in Vietnam* (Department of the Army, Washington DC, 1975) 131.
8. Larson and Collins, *The Republic of Korea*,134
9. R. P. Fox, *Air Base Defense in the Republic of Vietnam, 1961-1973* (Office of Air Force History, Washington, DC 1979,74-75).

Most Korean military units below the division level used tactical herbicides extensively because of their effectiveness in controlling perimeter vegetation. [11] Thus, it was not surprising that the Korean Ministry of National Defense jointly supported with the EUSA a subsequent recommendation for using tactical herbicides on the Korean DMZ in 1968.

THE PROPOSED USE OF HERBICIDES ON THE KOREAN DMZ

In the period of 1966 through 1969, United States and South Korean troops fought a series of skirmishes against North Korean soldiers in an undeclared war along the DMZ. Sarantakes has described in detail this "Quiet War". He noted that the frequency of attacks on South Korean and American troops increased in relationship to the density of the vegetation. Thus, by 1968 Army Engineers from EUSA and the First Republic of Korea Army (FROKA) implemented the use of heavy diesel plows and defoliants to remove much of the shrubbery along the demarcation line, making it harder for enemy troops to hide and conduct ambushes. [12] This was not the first time that herbicides were used to defoliate vegetation on the DMZ. However, 1968 was the first time that "tactical herbicides" were used to defoliate vegetation on the DMZ. Tactical herbicides were herbicides specifically developed and tested to be used in combat military operations, e.g., the use in Vietnam. [13] These tactical herbicides included Agents Orange, White and Blue and were not registered for commercial use, or for routine use on military installations. The only US military units authorized to spray tactical herbicides were the US Army Chemical Corps and the US Air Force Units that comprised Operation RANCH HAND.

In November 1963, EUSA recognized the success of defoliation operations in Vietnam conducted by personnel of Operation RANCH HAND. The Commanding General of the EUSA requested technical assistance from RANCH HAND in determining feasibility of conducting defoliation operations along the DMZ. [14] "*If effective the operation should (a) improve capability of UN Forces to detect and apprehend infiltrators, (b) provide prominent delineation of the southern boundary*

10. K. Kyong-hyun, C. Song-ryong, and L. Un-ho, *Vietnam War and Agent Orange*, Vol 1, English Translation (Medical Bureau of the Korean Armed Forces, Ministry of National Defense, Korea).
11. J. Park, *Scientific Evaluation of the Results of the Third Epidemiological Study on Defoliants* (The Korean Society for Preventive Medicine commissioned by the Minister of Patriots & Veterans Affairs, December 2006).
12. N. E. Sarantakes, The Quiet War: Combat Operations Along the Korean Demilitarized Zone, 1966 -1969 (The Journal of Military History 64:439-458. April 2000).

of the DMZ to insure against accidental overflight by friendly aircraft, and, (c) reduce amount of troop labor required to maintain cleared area immediately south of DMZ." The Commander of RANCH HAND visited EUSA on 16 November 1963, and provided recommendations to EUSA, but the decision to use tactical herbicides was denied due to the possibility of accusations of armistice violations, and a resulting potential propaganda harvest by the Communist world. [15]

Although the use of tactical herbicides was denied, the Chemical Corps of the Sixth Republic of Korea Army did apply a small amount of the commercial herbicide (2,4-dichlorophenoxy acetic acid, 2,4-D) in late 1963 in selected areas such as observation posts and guard posts to clear fields of fire. In 1965, the 2nd US Infantry Division requested that the use of herbicides be investigated for controlling vegetation within the anti-infiltration barrier on the DMZ. It was noted that commercial herbicides and application equipment were already on hand and capable of use. The request was staffed and again denied due to possible adverse North Korean reactions. [17]

In 1966, historical records of the EUSA stated: "*Good fields of fire and fields of observation are essential to DMZ Operations. Various methods including chemicals, mechanical devices, and hand labor may be used to clear these fields. Each method is effective, but conditions and locations will dictate which should be employed... "Plant growth may be killed at the roots through the application of chemical soil sterilants*"... "*Tests conducted by the US 3d Brigade, 2d Infantry division favor use of a herbicide called TELVAR MONURON which can be applied by use of the Power-Driven Decontamination Apparatus. Other herbicides were considered either ineffective or creative of undesirable effects outside the area of interest... Tests are planned for spraying the wire with waste oil or diesel oil as a preservative. Results remain to be seen.*" [18]

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13. [redacted] *Final Report, Vegetation Control Program CY 68*, 1-29.
14. Joint Message, *Request for Technical Assistance*, (Howard E. Kreidler, Colonel, USAF, Directorate of Operations, HQ, USAF to TAC and PACAF, 6 November 1963). Obtained from the Historical Records of the Eighth United States Army, Series 338, Washington National Records Center.
15. [redacted] *Final Report, Vegetation Control Program CY 68*, 1.
16. [redacted] *Final Report, Vegetation Control Program CY 68*, 1.
17. [redacted] *Final Report, Vegetation Control Program CY 68*, 1.
18. EUSA Study, *Analysis of DMZ and Contiguous Operations: The Rice Report.* (Historical Records of the Eighth US Army, 1966. Extracted by the US Army & Joint Services Records Research Center for the Department of Veterans Affairs).

Despite the comment on "other herbicides" the commercial herbicide 2,4-D was recommended with the commercial herbicide 3-(*p*-chlorophenyl)-l,l-dimethylurea (Monuron) for limited vegetation control on the DMZ in 1967. On 20 September 1967, the EUSA issued implementing instructions to the First Republic of Korea Army (FROKA) and the I US Corps to make test applications of Monuron and 2,4-D on flat terrain (2nd US Infantry Division) and in the mountains (21st ROK Infantry Division). It was decided that despite the lateness of the season (September/October 1967), it was necessary to train personnel and to evaluate spray equipment for any future operation, and to test any reaction from the North Korean government. [19]

Early in1967, as part of a general review of the Demilitarized Zone defenses, the United Nations Command (UNC), the United States Forces Korea (USFK), and the Korean Ministry of National Defense found that dense vegetation within the DMZ and contiguous areas continued to provide cover for North Korean infiltration by raiding parties. The vegetation in most areas had grown unencumbered since the Armistice and was an important part of the DMZ defensive problem. In March 1967, representatives of the Plant Sciences Laboratory, US Army Biological Laboratories, Fort Detrick, Maryland visited Korea and inspected typical vegetation growth in selected areas contiguous to the DMZ. Based upon this evaluation, the Plant Sciences Laboratory recommended the use of tactical herbicides, specifically Herbicides Orange and Blue, and the commercially available soil-applied herbicide Monuron (UROX 22) to control general and specific vegetation growth adjacent to the DMZ. [20] This recommendation was jointly supported by the US Department of Defense and the Korean Ministry of National Defense. [21]

The decision, however, to use tactical herbicides required obtaining approval of the United States Government, the Republic of South Korea (ROK) Government, and the United Nations Command. Numerous messages were dispatched during the period May through September 1967. Throughout September 1967, the US Secretary of State continued discussion of the program with the Republic of Korea Government. These discussions provided the acceptance of the program by the ROK Prime Minister, and on 20 September 1967 both governments (ROK and US)

19. HQ EUSA Ltr, *Special Analysis of the DMZ and Contiguous Operations* (Historical Records of the Eighth US Army, 1967. Extracted by the US Army & Joint Services Records Research Center for the Department of Veterans Affairs).
20. Young, *The History of the US Department of Defense Programs for the Testing, Evaluation, and Storage of Tactical Herbicides*. 51.
21. [redacted] *Final Report, Vegetation Control Plan CY 68*, 2. b6

gave permission for the use of the tactical herbicides to be sprayed in the area between the DMZ South tape and the Civilian Control Line, including the "Area Adjacent to the Southern Limit Line". This would total a strip of land that would be roughly 320 meters wide and 240 kilometers long. [22]

On 20 January 1968, RADM John V. Smith, Senior Member of the United Nations Command, Military Armistice Commission, disclosed in answer to North Korean charges of chemical warfare, that the UN Command may use defoliants to clear underbrush from fields of fire in the DMZ and thereby reduce Communist infiltration. [23]

THE SELECTION OF TACTICAL HERBICIDES

Why select tactical herbicides for defoliating the Korean DMZ in 1968 when commercial herbicides were available in 1967? The commercial herbicide 2,4-D and other "phenoxy" herbicides were widely used in Korea. Data from the Korean Yearbook of Agriculture and Forestry Statistics confirmed that in 1967, more than 187 metric tons of phenoxy herbicides, including 2,4-D, had been used in Korean agriculture and forestry programs. [24] However, there were four major reasons for selecting Agent Orange and Agent Blue:

- Both the Korean Forces and the United States Forces had extensive experience with using tactical herbicides for vegetation control around base perimeters in South Vietnam, and the mixture of 2,4-D and 2,4,5-trichlorophenoxy acetic acid (2,4,5-T), i.e., Agent Orange, was especially effective against a wide variety of herbaceous weeds and shrubs. Agent Blue (cacodylic acid) was very effective for controlling rapidly growing grasses, i.e., elephant grass, that also characterized the vegetation growing adjacent to base perimeters; [25]

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22. The "Area Adjacent to Southern Limit Line" was determined pursuant to the provisions of Article 2 of the Korean Ministry of Patriots & Veterans Affairs *Regulations Regarding the Scope of Area Adjacent to Southern Limit Line Where Defoliants Were Used*. The area refers to (1) the area 100 meters away from the north or south of the Southern Limit Line, (2) the area adjacent to observation posts, command posts and other important military installations built near the Area Adjacent to the Southern Limit Line, and (3) the area 30 meters away from the right or left side of the tactical road near iron railings (or fences) installed near the Southern Limit Line.
23. J. V. Smith, RADM, Senior Member UN CMACN confirmed that the United Nations Command was aware that the FROKA was preparing to use defoliants on the DMZ (8th Army Chronology, published by the Staff Historian Office, EUSA, APO 96301).
24. Yearbook of Agriculture and Forestry Statistics, *Consumption Trends of Herbicides by Group in Korea* (Published by the Ministry for Food, Agriculture, Forestry, and Fisheries, Seoul, Korea).

- The two tactical herbicides were readily available in South Vietnam in 1968. In FY 1968 (1October 1967 – 30 September 1968), the United States Air Force Logistic Command delivered more than 178,000 drums (each 208 liters) of tactical herbicide to South Vietnam. Tactical herbicides were available at the 20th Army of the Republic of Vietnam, ARVN, (South Vietnam) Ordnance Storage Depot, Saigon, and the 511th ARVN Storage Depot, Da Nang; [25]
- There was an extensively documented scientific history available on the safety of using 2,4-D, 2,4,5-T and cacodylic acid. As early as 1953, the two phenoxy herbicides were considered "essentially harmless" with only a moderate toxicity to mammals. In 1967, a major report published by Midwest Research Institute, Kansas City, Kansas, on the safety and ecological consequences of the repeated use of tactical herbicides in Vietnam concluded: (1) the direct toxicity hazard to people and animals on the ground is nearly nonexistent; (2) food produced from land treated with these herbicides will not be poisonous or significantly altered in nutritional quality; (3) toxic residues of these herbicides will not accumulate in the fish and meat to the point where man will be poisoned by them; and, (4) the primary ecological change is the destruction of vegetation and the resulting ecological succession in the replacement of this vegetation; [26] and,
- Perhaps equally importantly, by late 1967 the commercial formulations of 2,4,5-T herbicide were no longer available to be purchased in the United States. By FY-1968, the demand for and use of Agent Orange outstripped the ability of the US Department of Defense to purchase it. As a consequence, the US Government directed that all chemical companies that manufactured 2,4,5-T herbicide must provide that herbicide for the production of Agent Orange. Hence, if 2,4,5-T was going to be used for vegetation control on the DMZ in 1968, it would have to be formulated with 2,4-D as Agent Orange. [27]

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25. D. A. Craig, *Use of Herbicides in Southeast Asia*, (Directorate of San Antonio Energy Management, San Antonio Logistics Center, Kelly AFB, TX, USA, 1975). AFPMB LRS, Accession No. 188338.
26. W. B. House, L. H. Goodson, H. M. Galberry, and K. W. Docktor, *Assessment of Ecological Effects of Extensive or Repeated Use of Herbicides*, (Midwest Research Institute, Kansas City, MO, USA, 1967). AFPMB LRS, Accession No. 41243.
27. Joint Message, *Total National Production of Butyl Esters of 2,4,5-T Restricted for the SEA Defoliation Program*, (Commander of the Defense Supply Center, Richmond, VA to Army Logistical and Support Commands, 16 December 1967). AFPMB LRS, Accession No. 40654.

THE PROCUREMENT OF THE TACTICAL HERBICIDES

Based upon the approval of the Secretaries of State and Defense in the United States and the Government of Korea, the following message dated 17 Feb 68 was sent from the Chief of Staff of the United States Army to the Air Force Logistics Command (San Antonio Air Material Area, SAAMA); to the Commander, US Military Assistance Command, Vietnam (COMUSMACV); and to the 1st Logistics Command at Tan Son Nhut, Vietnam:

"***Request following herbicides be released to the US Army from RVN Stocks: FSC 6840-926-9094 – Herbicide Blue, 610 EA 55 gal drums; FSC 6840-926-9095 – Herbicide Orange, 350 EA 55 gal drums. Army will arrange transportation to and arrival in Korea not later than 20 March 1968.***" [28]

On 12 March 1968, the following message was sent from COMUSMACV to the Commander of the United States Eighth Army (GCUSAEIGHT), Seoul, Korea:

"***Direct transfer of following herbicides to the US Army from Saigon RVN Stocks and Subsequent Movement to Korea with a Delivery Date of 20 March 1968: 610 Drums of Herbicide Blue, 350 Drums of Herbicide Orange. Herbicide specified above loaded aboard SS Joplin Victory at Saigon on 9 March 1968. SS Joplin Victory, Voyage Number F8105B, Expected Time of Departure, Saigon 14 March with Expected Time of Arrival Inchon Korea 20 March 1968.***" [29]

The subsequent message was sent from GCUSAEIGHT to COMUSMACV on 10 April 1968 verifying:

"***Information requested is a follows: SS Joplin Victory arrived at Inchon, Korea at 1300 hours, 20 March 1968.***" [30]

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28. The authorization process required that a message be sent from SAAMA to COMUSMACV, RVN. This was accomplished on 17 Feb 68. COMUSMACV notified Commander, EUSA, Korea of the transfer of the required inventory, and the Air Force Chief of Staff finalized the transfer and provided a fund citation. These messages were in the United States National Archives at College Park, Maryland and were part of the records from the United States Air Force Judge Advocate.
29. This message was also in the National Archives at College Park, Maryland, and was part of the records from the United States Air Force Judge Advocate.
30. This message was also part of the records from the United States Air Force Judge Advocate.

The record is incomplete as to the movement of the tactical herbicides from Inchon Harbor on 20 March 1968 until their arrival at the FROKA units on the DMZ on 10 April 1968. [31] However, in Vietnam, Agent Orange drums were off-loaded directly from the cargo vessels at the Port of Saigon or the Port of Da Nang into semi-trailers. Each trailer held 48 drums and they were placed upright and transported to the RANCH HAND bases. This generally required appropriate coordination of vehicles, authorization for transport, the labor arrangements for the handling of the drums, and for a required time period of one to two weeks. [32]

DEPLOYMENT OF THE HERBICIDES ON THE DMZ

Following a series of planning conferences, a comprehensive vegetation control program was developed. On 10 March 1968, the Commander, US Forces in Korea and the Commander, First Republic of Korea Army were authorized to deploy tactical herbicides as part of the vegetation control program in the Korean DMZ. [33] To preclude the possibility of unfavorable propaganda and to ensure that defoliants would be properly employed with a margin of safety, the following constraints were placed upon the vegetation control program: (a) Defoliants were not to be deployed North of the Southern boundary of the DMZ; (b) During application, care was to be taken to ensure that there was neither run-off nor spray drift into areas North of the Southern boundary of the DMZ; (c) Defoliants would not be applied during precipitation or when rain was expected within 12 hours after application; (d) Extreme caution was to be exercised to avoid damage to food crops; (e) Defoliants would not be dispensed from aircraft of any kind; and (f) a Korean Military Assistance Group (KMAG) Representative 52 (a Chemical Corps Officer assigned to this subordinate element of the Eighth US Army) would be physically present whenever defoliants were deployed. By 20 March 1968, the first herbicide (Monuron) and equipment arrived in country from the United States. On 31 March, implementation of the Vegetation Control Program CY 68 was ordered to begin on or about 15 April 1968. As previously noted, on 10 April 1968 supplies of Agent Orange and Agent Blue were on-hand in forward locations near the DMZ. [34] However, the actual numbers of drums shipped from Saigon and arriving on the DMZ were 380 drums of Agent Orange and 625 drums of Agent Blue.

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31. [redacted] *Final Report, Vegetation Control Plan CY 68*, 3.
32. Young, *Agent Orange: A History of Its Use, Disposition, and Environmental Fate,* Chapter 3, Figure 3.11 and accompanying text.
33. [redacted] *Final Report, Vegetation Control Plan CY 68*, 4.
34. [redacted] *Final Report, Vegetation Control Plan CY 68*, 8-10. It should be noted that the allegation by US Korean Veterans that the two tactical herbicides were first sent to Camp Carroll is not supported by the messages, the required coordination time, or the on-site observations at the Korean DMZ.

No records were found in the archival searches that provided an explanation for why the shipping invoice and the receiving receipt had different numbers of drums. However, this difference in the number of drums of Agent Orange and Agent Blue as reported by Buckner may be resolved by examining the number of drums sent to the Port of Saigon from the Port of Mobile on 5 January 1968 (it took approximately 50 days for the herbicide to be transported to the Port of Saigon). Procurement Records obtained from one of the Chemical Companies that produced tactical herbicides indicated that pallets containing 380 drums of Agent Orange were shipped to Saigon from the Port of Mobile on the 5 January 1968 date.[35] It was also possible that the numbers were based on the number of drums per transport pallet. Another alternative is that the Commander, US Military Assistance Command, Vietnam wanted to ensure that sufficient herbicide was available recognizing that the handling of the drums could result in damaged and leaking drums, although the projected loss of damage was less than 1%.[36]

CONDUCTING THE DMZ SPRAY OPERATION, 15 APRIL -15 JULY 1968

Soldiers from the FROKA were responsible for the task of applying the herbicides, and for managing the entire project. Monuron (UROX 22) was spread by hand or mechanical broadcast beginning on 15 April 1968 and ending 28 April 1968. Approximately 7,800 drums (180,400 kg) of palletized herbicide were applied on 630 hectares or at a rate of 285 kg/ha.[37]

Applications of the tactical herbicides Agent Orange and Agent Blue began on 15 May 1968 upon the emergence of foliage, and terminated on 15 July 1968, The Orange herbicide was mixed with diesel oil at a ratio of 11 liters of Orange to 190 liters of diesel. EUSA furnished 7,000 drums of diesel oil for the mixing with the Orange herbicide. Since many application areas selected for spraying with Orange were relatively inaccessible for use of the modified M8A2 Decontamination Trailer, 22 liquid defoliant spray sets were employed. These units were insecticide sprayers commonly used in Engineer Entomological Services and consisted of a portable lightweight hypro-type pump with a standard gasoline engine.

35. Procurement and shipping information was provided to the Multi-District Litigation in RE: Agent Orange Product Liability Litigation, Case MDL 381, closed May 1985. Records are archived at the Washington National Records Center, Suitland, MD, USA.

36. Young, *A History of Its Use, Disposition, and Environmental Fate,* Chapter 3, Figure 3.10, and accompanying text.

37. [redacted], *Final Report, Vegetation Control Plan CY 68*, 6.

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The Republic of Korea Army also had available ten M106 "Mitey Mite" dispensers that were used to supplement liquid spray capabilities. The M106 was a commercial, backpack sprayer that consisted of a compact two-cycle gasoline engine that dispersed the herbicide through a 1.8 m hose. The tank contained 11 liters of liquid. The modified M8A2 Decontamination Trailers were used for spraying both Orange and Blue. The unit consisted of a 760-liter capacity tank and a 25 HP GED pump mounted on a 1 ½ ton trailer. A single hose reel allowed the operator to move approximately 15 meters from the trailer and direct a liquid spray through the Adjustable Beam-type spray gun at a rate of 75 liters per minute. [38]

Approximately 380 drums of Orange (79,040 liters) were to be applied on approximately 2,820 hectares. Agent Blue was to be applied as a liquid spray mixed with water also at a ratio of approximately 11 liters of herbicide to 190 liters of water. Approximately 625 drums of Blue (130,000 liters) were to be applied on approximately 4,660 hectares. All applications were done by ground-based spray systems. The use of masks and handling precautions were mandatory.

The [redacted] report noted that 3,345 FROKA soldiers were involved in the actual spray operations. No US military personnel were used to spray the tactical herbicides, or were involved in any of the spray operations, e.g., mixing of the herbicides and diluents. Only one US military person (a Chemical Corps Officer, LTC [redacted] monitored and reported on the activities of the ROKA Forces. And, as noted, the only year that the tactical herbicides were sprayed was 1968. [39]

THE FROKA HAD RESPONSIBILITY FOR THE SPRAYING ON DMZ

In 1967 (and subsequently in 1969) members of the EUSA did participate in herbicide spray operations on the Korean DMZ. In both 1967 and 1969 commercial herbicides were procured for the operation. Under the Department of Defense's Armed Forces Pest Control Board (AFPCB, now the Pest Management Board, AFPMB), the selection and acquisition of pesticides (including herbicides) for use by DoD military installations had to be approved by the AFPCB and be under the direction of the Installation Civil Engineer and the Command Entomologist. [40] In addition, any pesticide used must have regulatory approval of

38. [redacted] *Final Report, Vegetation Control Plan CY 68*, 7-8. Both Agents Orange and Blue were sprayed on the vegetation until saturated. This ensured complete coverage of the vegetation.

39. *Final Report, Vegetation Control Plan CY 68*, 20. T. Sypko, *Korean DMZ Vets & Agent Orange,* (VFW Magazine, January 2004) incorrectly noted that Agent Orange was used from April 1968 through July 1969. This incorrect information was used in the determination by the US Department of Veterans Affairs in decisions on presumptive compensation.

both the US (USDA at the time, now EPA) and the host country regulatory program. [41] The confirmation of this requirement is noted in a Report of a Staff Visit to Osan Air Base, Korea in December 1967 by a Civil Engineering Representative (the Command Agronomist) from the Headquarters of the Pacific Air Force. The Agronomist noted that the lush vegetation growing in and around the perimeter fence at Osan AB provided excellent cover for the entrance and hiding of infiltrators. He recommended that 2,2-Dichlorpropionic Acid (Dowpon) and 2-chloro-4,6-bis(ethylamino)-S-Triazine (Simazine) be applied. [42] Both herbicides had USDA Registration and were approved by the AFPCB and by the Korean Ministry of Agriculture, Forestry and Fisheries.

By Department of Defense Directive, the acquisition and spraying of Tactical Herbicides could only be done by the US Army Chemical Corps and the Air Force RANCH HAND program. Tactical herbicides did not come under regulatory review, nor could they be purchased by the Base Civil Engineer. [43] Indeed, the 1970 list of approved pesticides by the Armed Forces Pest Control Board noted that Agents Orange, White and Blue were available ONLY for tactical purposes and NOT for base type pest control. [44] Thus, in 1968 Agent Orange and Agent Blue could not be sprayed by members of the EUSA. The FROKA forces were not under the same Directive and thus the spraying of tactical herbicides on the DMZ was a Korean Military Project, by agreement of the Korean and United States Governments. From the beginning, the ROK assumed full responsibility for the entire on-site operation of organizing and spraying the defoliants. Although LTC [redacted] was an observer for the Operation, he stated in his report that: "*The FROKA have shown that they have the technical competence and capability to conduct defoliation operations on a massive scale.*" [45]

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40. Young, *The History of the US Department of Defense Programs for the Testing, Evaluation, and Storage of Tactical Herbicides*. 7-14. This Report described the distinction between tactical and commercially approved herbicides used by the US Department of Defense.
41. Editor Submission, *USDA Moves to Tighten Pesticide Labeling Regulations*, (Agricultural Chemicals, October 1963, pp 38, 125-128). The revision of the regulations also required the use of appropriate foreign language version of the label, in addition to the English version.
42. [redacted] Command Agronomist, *Report of Staff Visit to Japan and Korea*, (Approved by the Director of Operations & Maintenance, DCS/Civil Engineering, Headquarters Pacific AirForce, 8 January 1968)
43. Young, Agent Orange: *A History of Its Use, Disposition, and Environmental Fate*, Chapter 2. It noted that the AFPCB required all DoD agencies to use pesticides that had "Federal Specifications" in compliance with FIFRA. Tactical herbicides were required to meet "Military Specifications" and were exempt from regulatory approval or oversight process.
44. [redacted] *Pesticides and Pest Control Equipment*. AFPMB LRS, Accession 57009.
45. [redacted] *Final Report, Vegetation Control Plan CY 68*,28

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TACTICAL HERBICIDES USED ONLY IN 1968

In the latter part of 1968, significant controversy began to surround the use of Agent Orange in Vietnam. The assessment of the Midwest Research Institute Report in 1967 did not dampen the concerns of scientists. In July 1968, the American Association for the Advancement of Science and the National Academy of Sciences issued statements noting that many questions about the ecological effects of tactical herbicides in Vietnam remained unanswered and recommended an international field study under the sponsorship of the United Nations be undertaken to analyze the long-range effects of the herbicides on Vietnam's ecology. These controversies surrounding Agent Orange in Southeast Asia resulted in a significant restriction for its use in late 1968, and all uses terminated in April 1970.[46] The controversy also had the immediate effect in Korea of influencing the decision that tactical herbicides would not be used in 1969. Indeed, records confirmed that tactical herbicides were only used in 1968 and that alternatives would be selected for use in 1969.

Message from CG USAEIGHT to the CINCPAC (Commander in Chief, Pacific Air Forces), dated 20 September 1969 included the statement:

"Request this Headquarters be advised of the possibility of soil applied herbicides, excess in RVN, be furnished this Command at no cost to plan continuation of Vegetation Control Program to begin 15 April 1969." [47]

In a subsequent message from COMUSMACV to CG US EIGHTH"

Soil sterilant TELVAR (MONURON), FSN 6840-514-0644 on hand and excess in RVN is approximately 2,000 Fiber Drums, 160 pounds each, which is sufficient quantity to treat approximately 1,600 acres. This amount can be provided USAEIGHT on non-reimbursable basis. Recommend shipping instructions be provided directly to CG, III MAF, Da Nang, RVN." [48]

46. G. Reggiani, *Historical overview of the controversy surrounding Agent Orange*, (Chapter 3 in A. L. Young and G. Reggiani, *Agent Orange and Its Associated Dioxin: Assessment of a Controversy*, 1988). On 15 April 1970, the US Departments of Health, Education, and Welfare, Interior, Agriculture and Defense announced the immediate suspension of the major uses of 2,4,5-T. At the direction of the Department of Defense, RANCH HAND flew its last mission involving Agent Orange on 16 April 1970.

47. Joint Message, *Subject: Vegetation Control*. The message also noted that personnel from Fort Detrick were evaluating soil applied herbicides. [redacted] and [redacted] The *Lateral and Vertical Movement of Four Herbicides Applied to a Grassland Soil*, Technical Memorandum 212, Department of the Army, Fort Detrick, October 1970.

An additional confirmation was a **MEMORANDUM FOR RECORD** prepared in October 1968 by the Office of the Senior Chemical Advisor, US Army Advisory Group, Korea. The Memorandum described small field tests conducted at the DMZ in August and September 1968 that had been recommended by the Plant Sciences Laboratory, Fort Detrick, Maryland to test and evaluate different Monuron formulations and the soil-applied commercial herbicide Bromacil, HYVAR-XL. Thus in 1969, the plan was to apply both Monuron and Bromacil.[49]

FINDINGS AND CONCLUSION: THE VEGETATION CONTROL PLAN

The FROKA and EUSA in the initial planning had proposed to treat 8,110 ha, but in reality the FROKA personnel were only able to treat 7,330 ha, indicating that all of the Orange, Blue and Monuron that had been obtained were depleted. Thus, there was apparently no surplus Orange or Blue to be sent to Camp Carroll. More importantly, all of the Blue and Agent Orange drums became the property of the FROKA, and were rinsed with water or diesel fuel, respectively, and capped. [50] No records were found on the ultimate disposition of the empty herbicide drums by FROKA. The 7,600 fiber drums that had contained the Monuron were burned onsite after they were emptied. The disposal of the 7,000 drums that had contained diesel fuel also presumably became the responsibility of the FROKA, since there were no records in the Archives that any empty drums were sent to the Eighth US Army Material Center.

An additional confirmation that no surplus Agent Orange was present in Korea came for Joint Messages and documents of Operation PACER IVY, the Operation responsible for the removal of the remaining stocks of Agent Orange in Vietnam. One of the messages from PACAF, dated 13 October 1971 to all units in Southeast Asia pertained to the consolidation and processing of all Agent Orange stocks for removal from Vietnam or elsewhere to Johnston Island.[51] There were no stocks

48. Joint Message, *Subject Herbicides*. Monuron was routinely used in Vietnam as a soil sterilant for use around military facilities and fence lines. It was approved by AFPCB for use on military bases.

49. [redacted] Lt, US Army Chemical Corps, *Summary of 1968 Vegetation Control Tests*, (US Army Advisory Group, Korea, and Office of the Senior Chemical Advisor, October 1968).

50. [redacted], *Final Report, Vegetation Control Plan CY 68*, Detachment L. This Detachment provided the Standard Operating Procedures for Vegetation Control and Drum Disposal and was written in both Korean and English.

51. Young, *Agent Orange: A History of Its Use, Disposition, and Environmental Fate*. Chapter 4 documents Operation PACER IVY, the removal of Agent Orange from Vietnam. There were a series of Joint Messages and Memoranda noted in the Chapter.

identified from Korea, thus supporting the conclusion that there were no excess stocks remaining in storage after application on the Korean DMZ. This continued to confirm that the only Agent Orange stocks in Korea were those delivered to the Port of Inchon on 20 March 1968

Because of Directives 5154.12 and 4150.7, the Department of Defense gave the Armed Forces Pest Control Board/Armed Forces Pest Management Board the authority to set pest management policy *"applicable for all Department of Defense pest management activities in any unit, at any time, in any place, even when conducted by contract operations."* The significance of these Directives is that any herbicides used after 1961 on the Department of Defense's more than 600 world-wide installations had to be approved by the Board, and had to meet USDA's regulatory requirements, and all the requirements of FIFRA. [52] As previously noted the exception to these Directives was the development of the "tactical herbicides" sprayed in combat military operations in Vietnam, or as noted by US and Korean Governments approval as used adjacent to the Demilitarized Zone in 1968. This requirement also meant that Agent Orange or any tactical herbicide could not be sprayed in Korea by base personnel or their contractors at US Military Installations or disposed of in a routine manner. In addition, the AFPCB and the Department of Army, including EUSA, had strict guidelines on the handling and disposal of pesticides and pesticide containers, especially on large quantities of hazardous materials. [53, 54] It was noted in the August 1972 report at that time, the US Army's Environmental Engineering Research Unit, Edgewood Arsenal: *"The disposal of the Department of the Army's surplus pesticides of all types present serious problems. Significant among the various types of pesticides are large quantities of organochlorine insecticides and phenoxy acid herbicides. Recommendations are made...for phenoxy acid herbicides, including methods for incineration and for secondary disposal of ash and scrubbing liquids... and disposition in chemically or biologically active soils."* [55]

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52. [redacted] *AFPCB Recommended Statement on Use and Disposition of Pesticides*. The Board is located in the Forest Glen Section, Walter Reed Army Medical Center, Washington DC, 1971. AFPMB LRS Accession No. 61764.
53. Department of Defense Instruction, *Pest Control Operations at Military Installations*. Directive 4150.7 was prepared by the Office of the Assistant Secretary of Defense for Installations and Logistics, 23 July 1964.
54. USFK Regulation 700-17, *Use of Herbicides in the Republic of Korea*. This regulation was initially issued by HQ, United States Forces Korea, 12 March 1984.
55. US Army Medical Environmental Engineering Research Unit, Problem *Definition Study: Evaluation of Health and Hygiene Effects of the Disposal of Pesticides and Pesticide Containers*. AFPMB LRS Accession No. 86453.

Another finding and conclusion of the spray program involved the effectiveness of the tactical herbicides on the DMZ and was described by [redacted] as follows: b6

"The effect of Agents Blue and Orange were negated by regrowth of the vegetation in those areas that defoliation was not followed up by controlled burning. The application of these agents in areas other than the DMZ fence trace was of doubtful value. In addition, the drenching of vegetation with Agent Orange/oil mixture and use of Orange on grassy areas were a waste of time and effort." [56]

Buckner also realized that the real failure for the significant re-growth of vegetation in the case of Agents Orange and Blue was the dilution, mixing, and liquid spray reduced the overall effectiveness of the vegetation. [57] The herbicides 2,4-D and 2,4,5-T were commercially available and approved by the AFPCB as " Brush Killer", and it was formulated as the low volatile esters of 2,4-D & 2,4,5-T. Typically, "Brush Killer" was aerially applied at the rate 4.48 kg active ingredient per hectare, ai/ha. [58] Agent Orange was formulated as the concentrated high volatile esters and was applied aerially in Vietnam at the rate of 28 kg/ha. The recommendation for applications of Agent Orange on the DMZ was to dilute the Orange by pouring 11 liters of the Orange into 197 liters of diesel fuel, which meant that although the spray was diluted for the sprayer, the total amount applied by drenching a hectare of vegetation was similar to Vietnam, i.e., 82,460 kg ai applied to 2,820 ha or approximately 29 kg ai/ha. However, much of the effects on the vegetation did not occur as a consequence of the herbicides but rather as a consequence of the diesel fuel drying out the leaves before the herbicide could penetrate to the roots (In Vietnam, Agent Orange was not formulated with diesel fuel, but was applied as the concentrate).

After a thorough examination of the records found in the United States National Archives and a critical assessment of the [redacted] b6 report and supporting documents, the following conclusion can be made: **The allegations noted in the introduction were simply not based on military directives or the facts found within the historical records; namely, there was never any Agent Orange sent to or buried at Camp Carroll, or sprayed elsewhere in South Korea, except at the DMZ in 1968.**

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56. [redacted] b6, *Final Report, Vegetation Control Plan CY 68*, 25.
57. [redacted] b6 *Final Report, Vegetation Control Plan CY 68*, 26.
58. R. W. Bovey, *Uses of Phenoxy Herbicides and Their Methods of Application*, (Chapter 3, IN: R. W. Bovey and A. L. Young, *The Science of 2,4,5-T and Associated Phenoxy Herbicides*, John Wiley & Sons, New York, 1980).

A BRIEF REVIEW OF THE SCIENCE

Newton and Norris reported on a study of human exposures to 2,4,5-T and TCDD through dermal contact, research and monitoring of field applications and water quality since 1963, and studies of wildlife contamination occurring with field use of herbicides in the Oregon Coast Ranges of the United States. They noted the following:

"The human health risk from short-term exposure to a chemical (e.g., 2,4,5-T) is a function of the level, duration, and frequency of contact dose with the chemical, compared with the maximum level, duration, and frequency of exposure producing no symptoms. The frequency of exposure producing no symptoms is estimated from animal tests in the absence of controlled human experiments. We are operating under the general assumption that exposure has no health implications unless the chemical enters the body where physiological processes must deal with it." [59]

One of the studies by Newton and Norris involved the measurement of exposure of an individual that was more than 200 meters downwind of the spraying of 2,4,5-T. They estimated that during the first week after application, the resident received a total dose of 0.0019 mg 2,4,5-T/kg for a 70-kg adult, and a total dose of 1.9×10^{-11} mg TCDD/kg. Nearly half the total exposure occurred on day 1 of spraying (indicating the rapid half-life of 2,4,5-T). The acute no-effect estimates were 40 mg/kg for 2,4,5-T and 0.0001 mg/kg for TCDD. Exposure of applicators whose soaked clothing, or who otherwise came in continuous contact with a spray mixture (directly sprayed with 2.2 kg/ha eight times per day) had a net dose of 0.049 mg 2,4,5-T/kg (70-kg applicators). [60]

Newton and Norris also found in their monitoring programs that, with few exceptions, herbicide found in stream water was the result of direct application to the water. The low solubility of TCDD suggested that there would be a greater differential adsorption of TCDD on sediments in preference to 2,4,5-T, and that the actual levels would be lower than calculated.

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59. M. Newton and L. A. Norris, *Potential Exposure of Humans to 2,4,5-T and TCDD in the Oregon Coast Ranges*, (Fundamental and Applied Toxicology 1:339-346, 1981).
60. These conditions of soaked clothing/continuous contact were very likely the conditions encountered by personnel spraying the dilute Agent Orange on the Korean DMZ in 1968.

Lavy et al have also conducted numerous studies of phenoxy herbicide applicators. The results of one six-day study of both a backpack crew and from a crew spraying from a tractor showed that the degree of exposure was related to the worker's job. External dermal and respiratory exposures were measured and total intake of 2,4,5-T was determined from total urine collected from each worker for a 6-day period. The greatest amounts of exposure to 2,4,5-T were detected in mixers of the compounds and least amount in the sprayers. The exposure to 2,4,5-T averaged 0.0005, 0.586, and 0.033 mg/kg body weight for inhalation, patch, and internal measurements, respectively. These measurements indicated that the worker excreting the highest amount of 2,4,5-T (the mixer) received exposure levels significantly below those toxic to laboratory animals. [61]

Smith et al conducted a study of the blood serum levels of TCDD in a group of nine professional 2,4,5-T applicators in New Zealand. The nine applicators had sprayed 2,4,5-T for a range of 83-372 months. They measured the blood serum levels of polychlorinated dibenzo-*p*-dioxins and dibenzofurans, which were substituted with chlorine at the 2,3,7,8 position, in the nine applicators and in a matched group of nine control subjects. The average serum level of TCDD for applicators was almost 10 times that for the matched control subjects, while the average levels of all other congeners and isomers measured in the two groups did not differ substantially. They concluded that increased risks of cancer from brief exposure to phenoxyherbicides reported in other countries are probably not attributable to the TCDD that contaminated 2,4,5-T. [62]

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61. T. L. Lavy, J. S. Shepard, and J. D. Mattice, *Exposure Measurements of Applicators Spraying (2,4,5-Trichlorophenoxy) acetic Acid in the Forest*, (Journal of Agriculture and Food Chemistry 28: 626-630, 1980). The oral LD_{50} for 2,4,5-T was 300 mg/kg for rats and 100 mg/kg for dogs. In a chronic 2-year feeding study, the no-effect level for 2,4,5-T was at a dosage rate of 3 mg/kg per day. The hazard to wildlife from 2,4,5-T at used and recommended rates was negligible.

62. A. H. Smith, D. G. Patterson, Jr., M. L. Warner, R. MacKenzie, and L. L. Needham, *Serum 2,3,7,8-Tetrachlorodibenzo-p-dioxin Levels of New Zealand Pesticide Applicators and Their Implication for Cancer Hypothesis*, (Journal of the National Cancer Institute 84 (2): 104-108. This lack of evidence does not mean that TCDD does not cause cancer, but the current science does not establish a cause and effect relationship.

In 1982, the United States Air Force initiated the Air Force Health Study, a study of the Air Force personnel involved in Operation RANCH HAND – the program responsible for tactical herbicide spraying in Vietnam. The 20-year matched cohort study consisted of independent mortality, morbidity and reproductive health components. An appraisal of the study nearly a decade since the final follow up examination indicated that the results do not provide evidence of disease in the RANCH HAND veterans caused by their elevated levels of exposure to Agent Orange. [63]

Finally, the following studies may be relative to the exposure of FROKA soldiers who sprayed Agent Orange on the Korean DMZ in 1968. Studies of the properties of plant surface waxes of the cuticle layer have shown that Agent Orange, including TCDD, would have dried (i.e., be absorbed into the wax layer of the plant cuticle) upon spraying within minutes and could not be physically dislodged. Studies of Agent Orange and the associated TCDD on both leaf and soil surface have demonstrated that photolysis by sunlight would have rapidly decreased the concentration of TCDD, and this process continued in the shade. Studies of 'dislodgeable foliar residues' (DFR, the fraction of substance that is available for cutaneous uptake from the plant leaves) showed that only 8% of the DFR was present 1 hour after application. This dropped to 1% of the total 24 hours after application. Studies with human volunteers confirmed that after 2 hours of saturated contact with bare skin, only 0.15 – 0.46% of 2,4,5-T entered the body and was eliminated in the urine. [64]

After a thorough review of the science, the following conclusion can be made: **The prospect of any significant exposure and subsequent health impact to TCDD from Agent Orange in the FROKA soldiers or nearby residents seems unlikely in light of the environmental dissipation of TCDD, little bioavailability, and the properties of the herbicides and circumstances of application that occurred.**

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63. P. A. Buffler, M. E. Ginevan, J. S. Mandel, and D. K. Watkins, *The Air Force Health Study: An Epidemiologic Retrospective*, (Annals of Epidemiology 21 (9): 673-687, 2011).
64. A. L. Young, J. P. Giesy, P. D. Jones, and M. Newton, *Environmental Fate and Bioavailability of Agent Orange and Its Associated Dioxin During the Vietnam War*, (Environmental Science & Pollution Research 11 (6): 359-370, 2004).