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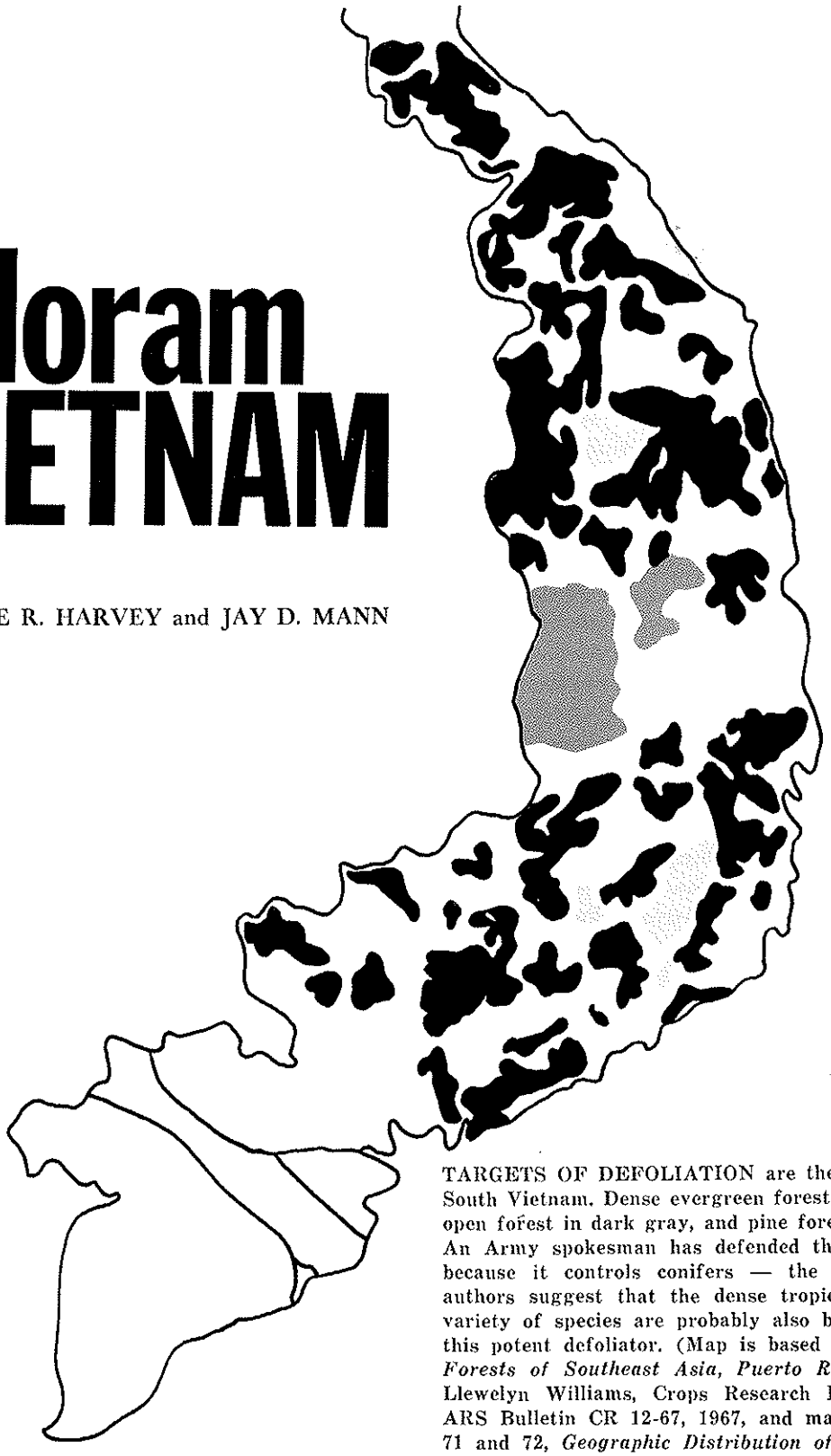
picloram in VIETNAM

By GEORGE R. HARVEY and JAY D. MANN



TARGETS OF DEFOLIATION are the forested areas of South Vietnam. Dense evergreen forest is shown in black, open forest in dark gray, and pine forest in lighter gray. An Army spokesman has defended the use of picloram because it controls conifers — the pine forests. The authors suggest that the dense tropical forests with a variety of species are probably also being sprayed with this potent defoliator. (Map is based on map 8, p. 252, *Forests of Southeast Asia, Puerto Rico and Texas* by Llewelyn Williams, Crops Research Division, U.S.D.A., ARS Bulletin CR 12-67, 1967, and maps 38 and 39, pp. 71 and 72, *Geographic Distribution of the Pines of the World* by William B. Critchfield and Elbert L. Little, Jr., U.S.D.A., Forest Service, Misc. Pub. 991, February, 1966.)

WHITE is the U.S. Army designation for an herbicide formulation being used in Vietnam which is extremely persistent, moves widely through the environment, and toward most plant life is the most toxic chemical yet discovered.

Tordon is manufactured by the Dow Chemical Co. Its common name is picloram or 4-amino-3,5,6-trichloropicolinic acid. It is mixed with the common herbicide, 2,4-D to make "WHITE." A recent article in *Chemical and Engineering News* mentioned WHITE only to say that it is "a combination of picloram and 2,4-D in amine formulation for woody plant control in areas where accurate spraying is essential. No detailed scientific studies on vegetation response to WHITE are available."[1]

On the contrary, detailed scientific studies of vegetation response are available, although not from Vietnam. These studies make it clear that even if precision spraying of specified targets were used, this would not restrict its damage to these targets.

Picloram was first announced by Dow Chemical about 1963 as an experimental herbicide for tree and brush control. Experiment station workers soon found that picloram differed sharply with other synthetic plant hormones by its extremely high biological activity. 2,4-D is rapidly metabolized in woody plants so that injury is mostly localized; 2,4,5-T remains active somewhat longer and is presently the herbicide most used for non-crop application. Picloram, however, seems to remain active in trees for prolonged periods and to circulate freely in the environment.

The concentrations of picloram needed to severely injure or to kill many broadleaved crops make it the most active herbicide yet discovered. Conifers can be destroyed by picloram application rates of 2.8 pounds per acre but, more important, as little as 0.4 pounds per 100 gallons will kill birch, willow, alder, hawthorn, cherry, and hickory.[2] Its activity is so sensitive to variations in climate and soil conditions[3,4] that the margin of safety on edible crops is very low. Thus, it is not surprising that picloram is not licensed by the Federal Drug Administration for use on a single American crop. A one per cent aqueous spray will annihilate crops of beans, tomatoes, peas, cotton, tobacco, grapes, cucumbers, sugar beets, and peanuts.[5] These application rates can be compared with the usual rates for commercial herbicides on major crops of two to six pounds per acre. In 1967, twenty-five million pounds of 2,4-D were used in South Vietnam, compared with a domestic use of ten million pounds on corn and thirteen million pounds on cereals, in addition to a few minor uses.

Most common shrubs will also be killed by a one per cent spray of picloram. For selective use in grain crops, a rate of no more than .06 pound per acre can be used after the cereal seeds have germinated.[6] Higher rates may damage the crop. Research on the scope of picloram is far from complete, yet some exceedingly sensitive plants have been found. Tobacco (a Vietnamese crop for local consumption in the village) is destroyed by treatments of .001 pound per acre[7] and a concentration of fifty parts per trillion in a spray will kill white clover.[8] The biological activity of picloram is generally greater than one hundred times that of 2,4-D.

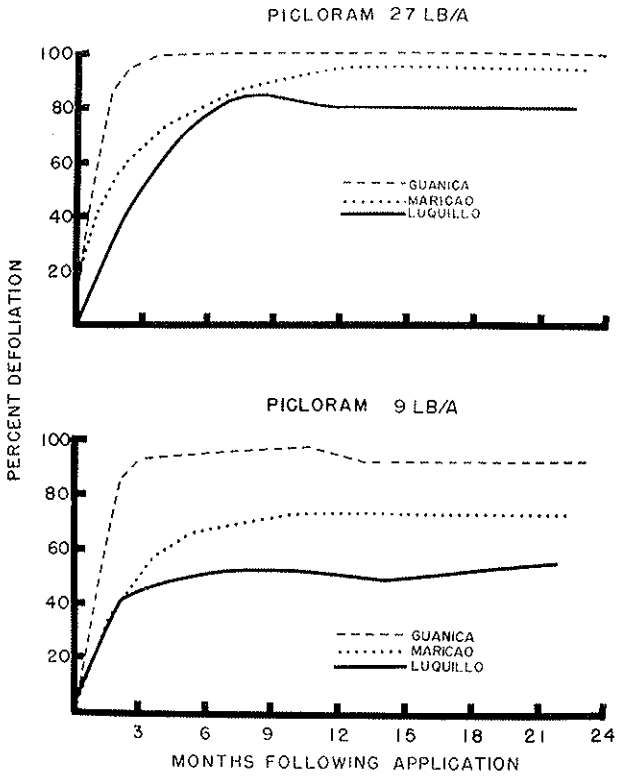
Although rice is the major crop of South Vietnam, accounting for more than ninety per cent of its agriculture, no reports have been published concerning the effects of picloram on rice. It is well known to American weed scientists, however, that cereals are susceptible to auxin herbicides when they are just emerging from the ground and when the flowering head is emerging. Thus, a persistent auxin herbicide like picloram can be expected to injure rice when it germinates or if used after germination, to severely hinder seed development.

A second remarkable feature of picloram is its enormous persistency in soils of many types. 2,4-D and 2,4-T remain active in soil for a matter of weeks at best. A revealing study of picloram use on a Puerto Rican jungle[9] was supported by the Department of Defense. Tropical rain forest areas treated with nine to twenty-seven pounds per acre of picloram remained essentially bare of leaves for the entire *two years* of the study.

Other work has shown that such prolonged activity is due to picloram remaining in the soil for long periods.[10] Not only did it take several months before any disappearance at all could be detected, but as the initial rate of application was increased, the lag before picloram started to disappear also increased. A report from Dow showed that a June application of picloram to control bindweed was still potent enough to damage several crops a year later.[11]

Picloram in sprayed land can be leached by rainfall into irrigation waters and severely injure crops in remote areas.[7] There is a high rate of water flow in monsoon forests, and picloram, being water soluble, can leave the forest via hydrological pathways to contaminate unsprayed regions, or can be leached into the earth.[12]

The persistence and stability of picloram are such that after application to an area "where accurate spraying is essential," it can be washed or the vapors blown to untreated land.[4] Vietnam is not lacking in either heavy rain or wind. The point was well made in a recent study conducted in the United States: "However, on large areas treated aerially, picloram (Tordon) could become a source of contamination by



PICLORAM WAS APPLIED to the soil in three forested areas of Puerto Rico, and the results studied for two years. These graphs show the percentage of defoliation at three-month intervals after the application. (Reprinted from *Weed Science*, courtesy of Dr. Clyde C. Dowler.)

movement of sprayed leaves and soil by wind and water to adjacent croplands. This hypothesis needs further study under field conditions."[4] Large areas *are* being treated aerially with picloram in Vietnam, but no studies of contamination by movement have been forthcoming from that field.

A dramatic illustration of the resistance of picloram to natural degradation phenomena to which other commercial herbicides are susceptible has been widely quoted: The incident concerns mules that were used to cultivate a tobacco field. They had previously been pastured on a lot that had been treated with picloram. When the tobacco began to grow, symptoms of leaf-cupping and stunted growth were noticed in an unusually spotty distribution in the field. It was learned later that picloram had been leached out of the mules' feces and picked up by the young plants and was the cause of the symptoms. It had passed completely through the mules' digestive systems and was deposited unchanged.[7]

Picloram by itself is relatively harmless to mammals. Dairy cows were unaffected by a diet containing five parts of picloram per million parts of forage. In fact, the picloram was recovered in the excrement unchanged.[13] Sheep were not harmed by ingesting 500 milligrams per kilogram of body weight.[14] 2,4-D is also harmless to mammals. But when the two are combined, the action of the one on some bodily organs reinforces that of the other, and the result is danger to mammals. A sheep was killed by a dose of thirty-six milligrams of picloram mixed with 2,4-D.[14]

It is this combination of picloram and 2,4-D that is used in Vietnam to make WHITE, as was mentioned earlier. The danger to mammals would be relatively short-lived, however, as the picloram and 2,4-D would separate in water, and the 2,4-D would dissipate quite rapidly.

Production figures for Tordon, a proprietary compound, are not available, but there is reason to think that more than five million pounds are being manufactured by Dow and used by the military.

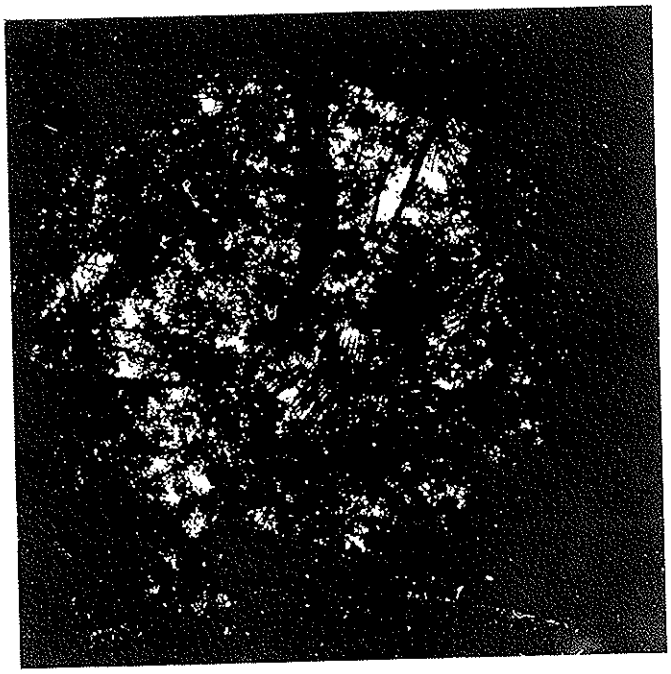
The entire domestic production (at least two million pounds) of natural *alpha*-picoline, the starting material for the synthesis of picloram, has been taken over by the U.S. government.[15] *Alpha*-picoline is also manufactured by a synthetic process, primarily by Reilly Tar at its Indianapolis plant. The present *alpha*-picoline capacity of this plant can be estimated at between six and nine million pounds, of which at least three million are over and above domestic needs.*

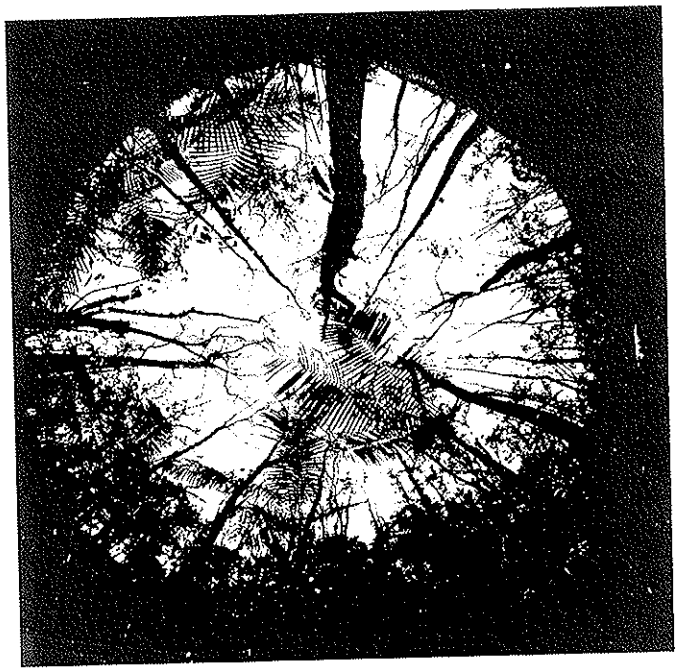
The molecular weight of picloram is twice that of *alpha*-picoline and by industrial process standards five million pounds of *alpha*-picoline should therefore yield more than an equal weight of picloram. All picloram is now purchased by the military.[16]

If five million pounds of picloram were spread uniformly over South Vietnam's forty-two million acres, this would be enough for double the rate at which selective weed control in cereals is safe. According to Dr. C. E. Minarik of Fort Detrick, WHITE is used because it "controls conifers."[17] Pines are the only significant species of conifers in Vietnam. Sprayed on Vietnam's limited pine forests only, five million pounds of picloram would be enough to kill them twice over.

However, indications are that its use is directed to the dense forests with a wide variety of species. Defense Department studies in Puerto Rico lead to this conclusion: "The broad spectrum of woody species susceptible to picloram makes it the single most

*Early in 1968, the plant doubled its pyridine-picoline capacity to twenty-five million pounds. Domestic production of pyridine was six and a half million pounds in 1965, and there is no reason to think that the demand has increased substantially. Reilly is therefore probably producing about eighteen million pounds of a mixture of picolines, of which no more than half, or nine million pounds, are alpha-picoline. The only other major use of alpha-picoline is in rubber manufacturing, which took three million pounds in 1965. Thus the industry has an apparent over-capacity of alpha-picoline which may be as high as six million pounds, but certainly no less than three million. There is now a shortage of alpha-picoline for non-military uses and last year about a half million pounds were imported, mostly from Japan. (Reference 16)

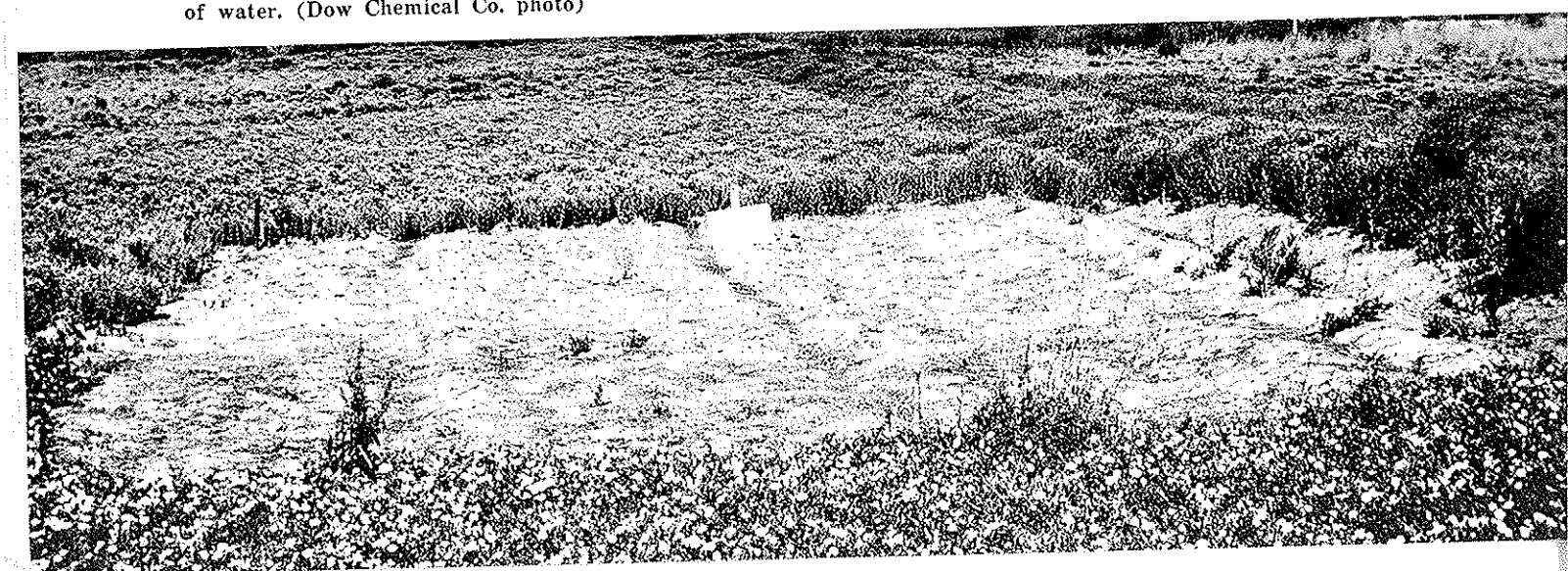


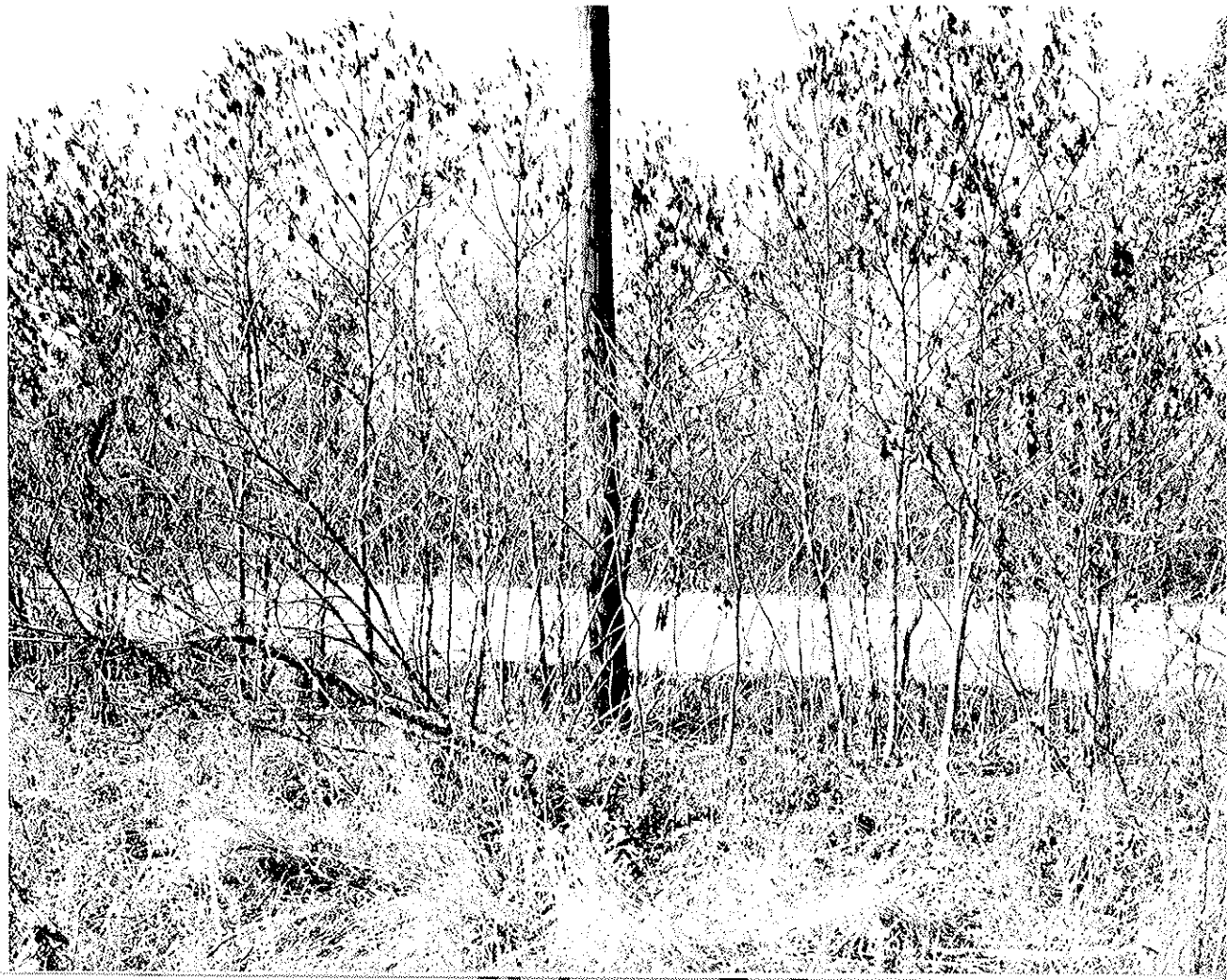


EFFECT OF PICLORAM ON FOREST CANOPY is dramatically illustrated in these two photographs. They were taken with an eight millimeter "fisheye" lens, looking directly upward. On the left, before treatment with six pounds per acre. On the right: three months after treatment. (Photos courtesy of Dr. Fred H. Tschirley, Crops Research Division, U.S. Department of Agriculture.)

BEFORE AND AFTER spraying with Tordon 101. The second picture was taken three months after the treatment. Active ingredients of Tordon 101 are Tordon (5.7 per cent) and 2,4-D (21.2 per cent). WHITE, the military herbicide used in Vietnam, is also a mixture of Tordon and 2,4-D. The full extent of its toxicity to plants is not known to anyone at this time. (Dow Chemical Co. photo)

THIS PLOT is bare because it had been sprayed one year previously at the rate of one pound of Tordon 212 per acre. The active ingredients of Tordon 212 are active Tordon (picloram), one pound per gallon, and 2,4-D, two pounds per gallon. It is usually applied in a one per cent spray—one gallon of Tordon 212 to one hundred gallons of water. (Dow Chemical Co. photo)





A TROPICAL RAIN FOREST is a delicately balanced and easily disturbed ecosystem. Interrupting the rapid nutrient cycle in this ecosystem by removing the canopy with a persistent herbicide like picloram could have some serious effects. The forest shown here is similar to those in South Vietnam. It is in Khau Yai National Park, Thailand. (U.S. Dept. of Agriculture Crops Research Division photo)

important herbicide for woody plant control. A few species tolerate high rates of picloram but many species tolerate high rates of other herbicides. Thus the use of picloram is particularly appropriate for the defoliation of forest types characterized by high species diversity. Such forest types are frequently found in tropical environments."[18]

A tropical rain forest is a delicately balanced and easily disturbed ecosystem. It is characterized by luxuriant growth, preponderance of woody plants, diversity of species, high temperature (with a mean of 80° F) and high rainfall (80 to 175 inches). The soils are incapable of holding large nutrient reserves because of the high rate of water flow and because they are "lateritic"—high in iron and aluminum compounds.[19]

Most of the nutrient pool is in the living vegetation, and when the vegetation is removed there is no reservoir to replenish or maintain soil fertility. Although each year great quantities of falling leaves, branches and whole trees become available (as much as twenty thousand pounds for every acre[20]), this material decomposes rapidly, and the greater part of it very quickly returns to the living vegetation as its nutrition. The remainder serves to keep the soil fertility stable. The major plant species in tropical rain forests are evergreen, and the cycling process continues imperceptibly year round without the obvious dormant period that occurs in temperate forests during which soils rebuild their nutrient content.

Interrupting this cycle by removing the canopy with a persistent herbicide like picloram could have some serious effects. In particular, there is a process that takes place when lateritic soils are exposed to the weather, described in the Department of Army Handbook for South Vietnam. "Where heavy rains wash off the humus, the silica dissolves out more easily than do the alumina and iron oxides, and the residue produces a red color. Potassium is generally lacking, and the combination of the iron oxides in the laterite plus the effect of rain and sun results in the soil setting like cement."[21]

The role of the forest seems to be that of protection. As far back as 1900 soil scientists were convinced that laterite soils could form only beneath forests and could become indurated, or set as described above, only after disappearance of the forest cover.[22] The unresolved questions are how long it takes for induration to occur after removal of the cover, and whether reforestation is possible. Reforestation seems to have an effect on the disappearance of induration, but has been successful only where the encrusted soil is broken up, heavily fertilized and carefully nurtured.[22] Natural reforestation on these crusts is open to question and most attempts to replant crusts have met with failure.

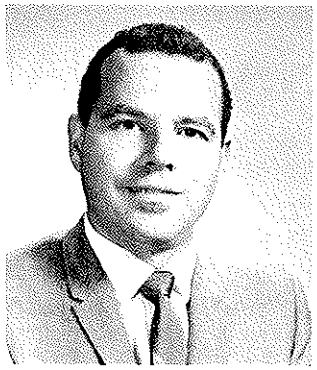
Depletion of the already meager nutrient content of tropical soils is another serious matter. In one experiment a fully exposed rain forest soil lost half or more of its organic carbon, phosphorous and nitrogen in three years of exposure.[20] Soil applications of picloram in Puerto Rico were still causing ninety-six per cent defoliation twenty-four months after application when the study was concluded.[9] How much longer it remained potent is not known. The persistent nature of picloram and the effects of abnormal leaching and

high temperatures are reinforcing in their destructiveness. By the time picloram concentrations become low enough to allow germination and growth of plant life, the physical and biological condition of the soil may prevent them. Still further deterioration would then occur. Together these factors could leave large areas of Vietnam permanently damaged.

Unfortunately, vegetation is not the only component of the ecosystem affected by defoliation. With destruction of the basic source of nutrition, all food chains supported by the source would likewise be destroyed. Hundreds, perhaps thousands, of species of insects, birds and mammals depend on the forest vegetation for their existence and also contribute heavily to its stability. Their populations will unquestionably be decimated, making recovery of defoliated areas even more difficult. A recent news report from Vietnam indicates that many species in the forest areas that have been defoliated are dying or migrating.[23]

In summary, the use of WHITE to defoliate in Vietnam will have many undesired consequences. Its high biological activity might make it very difficult for edible plant life to grow in future years. The full extent of its toxicity to plants is not known to anyone at this time.[12] The military appeal for this herbicide is obvious: pilots spraying it don't have to return for reapplication. But the Vietnamese farmer does want to return.

George R. Harvey received a doctorate from the Massachusetts Institute of Technology in 1964 and is an industrial organic chemist.



Jay D. Mann is an industrial plant physiologist. He received a doctorate from the University of Wisconsin in 1957.

Both are currently working at Monsanto Company in St. Louis. In this article they are speaking as individuals and not as representatives of Monsanto. (Martin Schweig photos)

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