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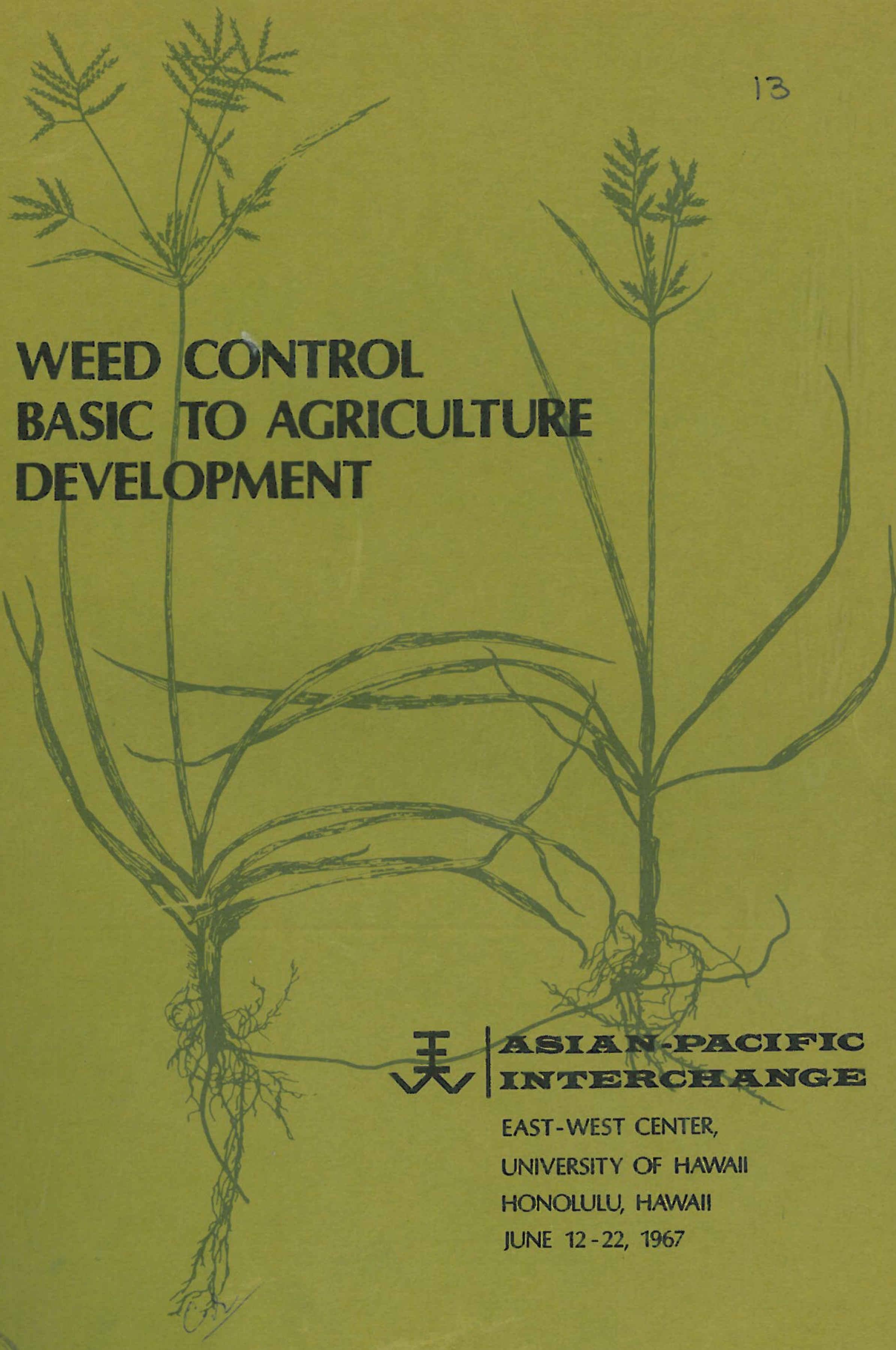
WEED CONTROL BASIC TO AGRICULTURE DEVELOPMENT



ASIAN-PACIFIC INTERCHANGE

EAST-WEST CENTER,
UNIVERSITY OF HAWAII
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JUNE 12-22, 1967

WEED CONTROL
BASIC TO
AGRICULTURE DEVELOPMENT

Edited by
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D. L. Plucknett
H. F. Clay

PROCEEDINGS OF
THE FIRST ASIAN-PACIFIC WEED-CONTROL INTERCHANGE

June 12-22, 1967
University of Hawaii, Honolulu
and the Island of Kauai

Sponsored by the University of Hawaii,
Institute for Technical Interchange, East West Center
and the
College of Tropical Agriculture

Plate provided by D. L. Plucknett and D. F. Saiki from a forthcoming book, *Weeds of the Tropics*, with illustrations by Avery H. Youn and Susan Nakagawa.

THE INSTITUTE FOR TECHNICAL INTERCHANGE (ITI) is one of three institutes of the East-West Center, a federal institution created by the United States Congress in 1960, in co-operation with the University of Hawaii. The Center's purpose is to increase cultural and technical interchange between the people of East and West–mutual understanding through the exchange of people and the exchange of books.

Each year about 600 students and senior scholars from more than 30 countries and territories study or do research in postgraduate and undergraduate programs at the University through scholarships and grants administered by the Institute for Student Interchange (ISI) and the Institute of Advanced Projects (IAP); the Institute for Technical Interchange conducts conferences, seminars, and training courses involving more than 1,500 participants in programs in Hawaii or in field work in the Asian-Pacific area. East-West interchange also is fostered by the East-West Center Press, the East-West Center Library, and the international Conferences and Seminars program.

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1 INTERCHANGE SUMMARY

The first "Asian-Pacific Weed Interchange" conference convened on June 12, 1967, at the University of Hawaii, Honolulu, and terminated on the island of Kauai on June 22. The meeting was co-sponsored by the East-West Center's Institute for Technical Interchange and the College of Tropical Agriculture, University of Hawaii. There were 87 university, government agency and chemical company participants in attendance from the following countries and territories: India, Thailand, Japan, Philippines, Malaysia, Pakistan, Indonesia, Taiwan, New Zealand, Western Samoa, American Samoa, New Guinea, Cook Islands, Tonga, Okinawa, New Caledonia, New Hebrides, Fiji, U. S. Trust Territory of the Pacific, United Kingdom, West Germany, Hawaii and mainland United States. The Interchange consisted of the presentation of oral papers, panel discussions, field trips and work shops.

All participants showed a keen interest in the weed problems of the Asian-Pacific area and shared readily in relating their experiences with others. By far, the excellent exchange of information between industry and government personnel was most appreciated. All participants agreed that this close working relationship should be continued in order to best serve the needs for the development of weed science in the Asian-Pacific area.

The Interchange established the pressing need for weed science in the Asian-Pacific area, and at the workshop meetings on the island of Kauai an organization, "Asian-Pacific Weed Science Society", was formed to facilitate the interchange of current weed control information and to promote research in weed science. The following interim officers were named to lead the society:

Chairman:	Dr. Marcos Vega University of Philippines
Secretary:	Dr. R. Romanowski University of Hawaii
Coordinators:	
Asian region –	Dr. S. Matsunaka National Institute of Agricultural Science, Japan
Pacific region –	Mr. Kenneth Newton South Pacific Commision
Industry –	Dr. Joe Antognini Stauffer Chemical Co., U.S.A.

We are all indebted to Vice Chancellor Y. Baron Goto of the East-West Center and Dean C. Peairs Wilson of the College of Tropical Agriculture for their excellent support of the program. It is with great pleasure that we forward this proceedings of the meeting.

Program Committee:
H. F. Clay
D. L. Plucknett
R. R. Romanowski

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2 GENERAL SESSION

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WELCOME TO THE WEED CONFERENCE

Thomas H. Hamilton [1]

It is, of course, customary for the president to give an address of welcome to visitors to the campus. It seems unnecessary, for if you were not welcome you would not have been invited. But I suppose such occasions do call for the presence of an administrative shill.

But I should like to do a little more than simply welcome you this morning, for, as I pointed out to Dean Wilson, I stand firmly opposed to weeds. But really you have, within the subject matter of your conference, what to me is a fascinating example of how one cannot predict the eventual practicality of what starts out as simply a scientist's curiosity. The subject matter of your conference is one of the best bits of evidence I know that it is futile to try to delineate strictly between basic, or pure, research and applied research.

The value of chemicals to be used in chemical weed control probably exceeds a hundred million dollars, and these chemicals are used to treat probably from 40 to 50 million acres of crop land. The financial return to the nation's farmers, in terms of labor saving due to the use of chemical weed control, may indeed now be approaching a half billion dollars. This means that the dollar return per year from this single contribution of plant research would exceed the cost of all basic plant research conducted in this country during its entire history. Thus, it seems to me that the practicality of this development, as measured in the usual terms of dollars and cents, certainly has been established. Now it would seem of interest to inquire into the history of this development with the objective of learning how it came about.

Everyone is familiar with the response of plants to light and to gravity. For example, a potted plant grown indoors inclines it leaves and grows toward the light. Similarly, if a potted plant be laid on its side, it will be found that the top will straighten itself and grow up, and the roots will renew their growth in the soil and grow down. Such observations were made by Charles Darwin, a liberally educated man, as early as 1880. He also showed that removal of the root or shoot tip precluded the response. Darwin wrote, "We must, therefore, conclude that when seedlings are freely exposed to a lateral light, some influence is transmitted from the upper to the lower part, causing the latter to bend." The truth of this statement was emphasized by Boysen Jensen in 1910 who showed that the stimulus could be transmitted across a wound gap. Thus, if the tip of a stimulated, decapitated plant were replaced, normal bending would ensue.

From these primitive experiments it was concluded that the growth controlling substance was produced in the top and diffused downward, controlling the growth of the lower portion of the shoot.

The question next arose as to whether this growth controlling substance was a stable chemical entity which could be isolated from plants and reapplied to other plants. This question was answered very effectively and simply by F. W. Went, who showed in 1926 that if a plant tip were placed upon a gelatin block, the growth substance would diffuse out into the gelatin. If subsequently the gelatin block were placed on a decapitated plant, normal growth would ensue.

These studies were culminated in the isolation by Kogl, Haagen-Smit and Erxleben in 1934 of one of the plant growth substances and its identification as indole-3-acetic acid (IAA).

From 1934 until 1939-1940 the plant growth hormone remained a laboratory curiosity. Indole acetic acid proved to be a difficult compound to work with under other than laboratory conditions. It was an expensive and rather delicate chemical. A knowledge of the sturcture of IAA suggested, however, that other much less expensive and more stable chemicals might have a similar action. These hopes proved justified.

During the period of 1939 to 1941 there gradually arose the concept that the plant growth hormones might prove to be a potent substance for killing plants, growing themselves to death, as it were. About 1940, and this period is somewhat vague because of wartime security restrictions which had been imposed, Kraus and Zimmerman in this country, and Templeman, Slade, Blackman, Nuttal and other workers in England, began tests of materials with plant growth regulating activity as plant poisons.

It soon became apparent that not all plants were equally sensitive, and thus some weedy plants could be selectively killed without harming crop plants, particularly the grass and cereal grain crops.

These developments remained wartime secrets until about 1945 when the chemical weed control industry was born. It is this infant of some twenty-two years which has now grown into the multimillion dollar industry which I spoke of previously.

Now, several points are to be stressed. First, the original researches were prompted solely by the curiosity of scientists, by their desire to explain something of what controlled plant growth—and curiosity about the world is basic to education. Secondly, early researches, and indeed those until 1947, were done almost entirely under laboratory and greenhouse conditions with the objective of finding out as much as possible of the plant growth regulators without regard to their economic feasibility. They were, in short, researches of such a long range and basic type that no industry could or would support them. Even government laboratories, subject as they are to pressures from growers to answer immediate problems, were unable to conduct them. The research advances could only have occurred in the university research laboratories. They could have been initiated only in the liberal tradition.

And so you see, weeds are something very special to me, for it has given me an example I have used many times to demonstrate the importance of basic research, the necessity to bless simple scientific curiosity, and the values of liberal education.

I trust you will have an excellent meeting.

[1] President, University of Hawaii

MEETING THE WORLD FOOD CRISIS THROUGH WEED CONTROL

Spark M. Matsunaga[1]

It is with extreme pleasure that I address you this morning, for as we look to the situation in the Middle East and in South-East Asia, it seems that what we are doing here today in an international interchange, in an atmosphere of friendship for mutual betterment, is in the nature of a small miracle. It is my fervent hope that through conferences such as this, where men of different nations gather together for the resolution of common problems, we who pride ourselves as belonging to the highest order of the animal kingdom may some day disprove Plato's observation that only the dead have seen the last of wars.

Aside from the battles against each other, mankind today is engaged in a race between the increase in the world's population and the increase in food production, and according to experts we are losing the race. This is not to say that the total world food production is decreasing, for in fact, while the production of food in many of the developing regions has fallen slightly in recent years, the total world food production has been on the increase. But the population is increasing so rapidly that the per capita increase in food is not keeping up with population growth, and many countries have less food per person today than they had a few years ago, even though they have actually increased their food production.

It is highly important, therefore, that every effort be exerted towards increasing our world food production. One avenue of approach is through weed control, which is basic to agricultural development in any part of this earth, and you are to be commended for your participation in this far-sighted conference.

The scientific advances since World War II have created so many new opportunities, opened so many new doors, that we need to stop to consider if we are taking the best possible advantage of these opportunities . . . or, if we are taking advantage of them at all.

We need to take a hard, calculating look at weed control to see if we are utilizing known technology to the fullest extent possible. We need to look at it from the standpoint of the special problems and opportunities that exist in this part of the world.

I do not believe anyone would deny that weed control is a necessary factor in agricultural development. We may go so far as to say that without it, no nation can build the kind of dynamic agriculture that is needed to produce food for the ever increasing numbers of people.

Throughout the world, there are more than 30,000 species of weeds. About 1,800 of these cause serious economic losses each year. Anywhere from 50 to 200 commonly infest and damage the major food crops of the world.

Scientists in the U.S. Department of Agriculture tell me that weeds cause a 30-percent drop in yields of maize in tropical countries of the world.

In India, weeds reduce production of food crops from 30 to 100 percent. This is one of the major causes of low crop yields in that country.

In Japan, 191 weed species reportedly harm rice yields, and 30 of them cause serious damages.

No matter where it is, scientists tell us that it is essential to control all weeds in the protection of a major crop, even though some of them may not be very dense because the uncontrolled species may otherwise become dominant and eventually destroy the crop.

The question is: What kind of control do we use?

Recent tests on rice in five Asian countries have shown that although hand-weeding returns the greatest yields, it is expensive and impractical where labor must be hired. By far, the cheapest and most efficient weed control in terms of rice produced per dollar invested, was a single application of an experimental herbicide.

In comparing good cultural practices with chemical control in rice fields in the Philippines and in West Pakistan, chemical control increased yields by nearly 50 percent. If this increase is typical of those that may be expected in other areas, then the use of herbicides for selective control of weeds in rice could have a significant impact on world rice production.

Perhaps the most dramatic example of how successfully herbicides can be used in rice production is to be found in California. Only 7½ manhours per acre are required to grow rice there, as compared with 400 to 900 manhours in many other parts of the world. In little more than 10 years, yields in California have risen from 2,500 to over 5,000 pounds per acre. The increase in yields and in efficiency of production can be attributed to many things such as good soil and climate, abundance of water, and long-established reliance on research results, but the primary factors were efficient weed control methods and mechanization. Currently, propanil is being widely used as a post-emergence herbicide to control water-grass and other weeds in rice. This particular chemical has only recently come into use in Japan and in some areas of Southeast Asia.

Japan, with its highly advanced agriculture, has also cut its labor needs for producing rice. Use of herbicides enabled a 30-percent drop in manpower requirements.

In effect, the use of herbicides represents an added production tool or substitute for other sources of energy for increasing farming efficiency. Many countries have adequate labor, it is true, to do the necessary weeding by hand. And in these countries, chemical weed control is very low in priority. If, however, the weeds were controlled chemically and the labor devoted instead to improving irrigation – a prime factor in rice production – yields could be increased further. Moreover, the labor released from hand-weeding could be used to apply fertilizer, and to plant and cultivate additional land to rice, thus increasing the food supply. This holds true for other crops as well as rice.

Herbicides have helped bring about what one scientist in the U.S. Department of Agriculture calls a "second-generation breakthrough" in production efficiency – that is, the increase in yields and quality due to improved weed control methods now provides an opportunity for a new research cycle involving all phases of agricultural production, which can result in still greater accomplishments.

Turning to my own State of Hawaii, there are many critical weed problems here that continue to hamper efficient production. Unfortunately, many of the desirable weather conditions that result in high productivity also result in heavy weed growth. The moderate year-round temperature encourages year-round growth of weeds. Wide variations in rainfall encourage the growth of widely differing species. This varying rainfall pattern has the added disadvantage

[1] United States Congressman from Hawaii

of complicating the use of chemical and other weed control measures.

Each of the diverse crops grown here – such as sugar cane, pineapple, coffee, vegetable crops, forage crops, macadamia nuts, and ornamentals – requires specific cultural practices, and specialized weed control measures.

Frequently, the same herbicides that do so well in the continental U.S. will not give the same results here. They may give poor and uneconomical control, or actually cause serious injury to the crop being treated.

So, in choosing the weapons we need to control weeds in Hawaii, we must consider a combination of factors – unusual climate, rainfall, soils, weed populations, and crops.

Growers here are concerned with a vast number of annual and perennial broadleafed weeds and weed-grasses involving many plant families, genera, and species. The perennial grasses and sedges, such as bermudagrass, Johnsongrass, tall panicum, torpedograss, Hilograss, green kyllinga, and field sedge are the most difficult to handle, as they spread very rapidly and resist effective control.

The cost of control is high. Recent figures show that about 12 percent of the cost of producing coffee can be attributed to weed control. Sugar cane growers spend about $8 million each year to control weeds in their fields. Many vine crops, such as cucumbers and watermelons, cannot be grown without herbicides, as the dense ground vines will permit little or no tillage. That we here in Hawaii have considered the problem of weed control very seriously is evidenced to some degree by the employment of eight full-time experts and twenty-five part-time researchers in this area by the government and private industry.

Now, what about the adequacy of present weed control methods in Hawaii? I believe our experiences here can be related to other areas in the Asian-Pacific region.

Effective chemical and biological methods of controlling certain weeds in the major agronomic crops have been developed. A wide variety of chemical compounds are now being used rather successfully on sugar cane plantings. Advances have been made in controlling weeds in pineapples, and in coffee and macadamia nuts. Many new herbicides are useful in controlling weeds in vegetable plantings, particularly in tomatoes, cucumbers, lettuce, and sweet corn.

Regardless of the method used, however, it is difficult to control weeds selectively year after year. There is a natural tendency for tolerant strains and species to increase in population after continual herbicide usage.

For example, use of herbicides to control annual weeds in sugar cane may release weeds like Johnsongrass or nutsedge from competition. The newer species then pose an acute problem, and we need to begin the control process all over again.

The same pattern is found in the growing resistance of prickly pear cactus plants to a disease that is normally used to control them. The few scattered resistant strains will undoubtedly multiply and the undesirable plants may once again become a serious problem.

Consequently, continuous research is necessary to hold the ground already gained and to develop new knowledge and practices to meet the changing needs of agriculture, not only here in Hawaii, but throughout the Asian-Pacific area. Educational programs are essential too, to keep growers continuously informed of the newest developments that may affect their operations. And obviously, regulatory programs are essential to keep serious weed problems from spreading from one area to another.

A source of considerable pride to me is the advances that the Hawaii Agricultural Experiment Station located at the University of Hawaii have been making on the specialized problems of weed control in Hawaii. Under the direction of Dr. Roman Romanowski and Mr. Yukio Nakagawa, for example, a vegetable herbicide screening program was initiated in 1962 at five branch experiment stations typical of the major vegetable growing areas of the State. Vast amounts of information have been accumulated, and the results are being disseminated continuously by the Hawaii Cooperative Extension Service. Growers here are constantly urged to work closely with their county agents in developing successful herbicide programs.

The sugar cane industry here has conducted some excellent research of its own on problems of weed control. Much credit goes to Dr. Noel S. Hanson, former head of Weed Science Research and Dr. Wayne H. Hilton, present head of Weed Research at the Experiment Station of the Hawaiian Sugar Planters' Association. Dr. Hanson and his colleagues have made major contributions in developing specialized techniques for distributing herbicides.

Many new opportunities are opening up for future advances. The Agricultural Research Service – the main research agency in the U. S. Department of Agriculture – is involved in many of the basic studies leading to improved ways of controlling weeds. Much of this work can be adapted to the special needs of our part of the world.

Work is underway to increase not only the effectiveness, but also the safety of herbicide application. New methods of application may make it possible to reduce the amount of herbicide needed for control through more accurate concentration on the weeds themselves.

One sprayer, now under development, is designed to recover and reuse the herbicide that misses the weeds. Another avoids drift by applying the herbicide with foam. Still another utilizes wax bars impregnated with 2,4–D and trailed above low-growing crops to contact only the taller weeds.

Basic studies on how plants grow and how herbicides get into plants and act on them will contribute towards much greater selectivity of weed control. Herbicides of much greater sophistication are in the process of being developed, as well as systems for rotating herbicide use so that weeds can be controlled without building up harmful residues in the soil.

Research on the nature of plant dormancy could lead to some rather interesting new ways of using chemicals on weeds. Chemicals could, perhaps, cause all weed seeds in the soil to germinate at the same time for fast and easy control. They could extend the dormancy of weed seeds until they lose viability. Or they may be used to prevent fertilization of weed flowers, or interfere with the ability of weeds to tolerate drought or low temperatures.

Scientists in the U. S. Department of Agriculture are also trying to find ways to extend the effectiveness of cultivation and crop rotation to be used along with chemical controls. Weed diseases are being studied as one method of biological control. The use of snails and fish, like Hawaii's weed-eating carp, is also under investigation.

Current studies will provide a much better understanding of the effects of repeated use of herbicides on crop growth and on the physical and biological condition of the soils. Scientists know, for example, that some preemergence herbicides can make plants more susceptible to certain root diseases . . . and that the interaction among herbicides, insecticides, and fungicides can increase susceptibility to injury. On the other hand, scientists also have evidence that crop tolerance to herbicides may sometimes be *improved* where fungicides are used. A clarification of the chemical and biochemical relationships involved will contribute toward better use of herbicides.

One point to remember in discussing the future of weed control is that it cannot single-handedly raise the level of agricultural development. For greatest effectiveness, weed control must be properly integrated and balanced with other production aids, such as improved varieties, control of insects and diseases, mechanization, fertilizers, and irrigation. It would be folly, for example, to plant and irrigate an improved crop variety without taking the necessary steps to control weeds, insects, and diseases . . . or to fertilize a crop that cannot give a proper response.

An example is in India, where one of the main needs is a stiffer, nonlodging rice that will not fall down when fertilization rates are raised to increase yields. Incidentally, a new variety developed in the Philippines under the direction of the International Rice Research Institute has exactly this desired characteristic. Sizeable amounts of the variety – known as IR-8 – are being test-grown in India.

This need for integrating desirable production practices to achieve greater food production cannot be overstressed. As stated earlier, agriculture faces tremendous challenges in meeting future demands for food for increasing numbers of people throughout the world. The appalling fact is that world food supply is increasing at an average rate of only 1 percent a year, while the population is growing by more than 1.8 percent a year. At this rate, the population of the world will be doubled by the end of the century. We can expect 6 billion people within 33 years. And we cannot adequately feed 3 billion people today.

The most realistic answer to this growing world food crisis is *not* transferring food from one nation to another – this is only a temporary remedy – but for the less fortunate nations to develop a strong agricultural economy and greater self-sufficiency in food production.

I believe the so-called developing nations *must exert every effort* to work with the technologically-advanced nations in order to adapt new ideas and techniques to improve their agriculture. Many public and private agencies in the United States and other countries are now cooperating in this effort.

Agricultural scientists and technicians from the U. S., for example, are working in 39 countries to help them develop the education, credit, cooperatives, and research institutions needed for modern farming. Special cooperative research projects are underway within many of these countries to help them solve longstanding barriers to food production. Numerous projects are underway in the U. S. to develop special high-protein foods that people in these nations can readily learn to like. Thousands of future agricultural leaders are being trained in the U. S. to assume the all-important job of building their own agriculture. Approximately 600 research projects conducted by scientists in many of the developing nations under terms of Public Law 480, the Food for Peace Act, have some application to problems of increasing food production. Only last year an amendment to this law which I offered was adopted by the U. S. Congress to establish a research center for tropical and sub-tropical agriculture. It is hoped that this center will be situated in Hawaii and will include weed control as part of its program.

The technology for development is available. We are eager and willing to cooperate with those needing assistance. But the initiative must come from the developing nations themselves.

All of these nations have many problems that require special attention. But, at the same time, they cannot overlook the urgent need for weed control in establishing a basis for feeding their growing millions. I am convinced that such research will provide some of the most significant opportunities for future advances in agriculture.

I bid you good luck and wish you the greatest of success in your deliberations.

ROLE OF EAST–WEST CENTER IN ASIA AND THE PACIFIC

Y. Baron Goto[1]

Let me begin by telling you something about the East-West Center, which is one of a number of unusual activities you will find at the University of Hawaii.

The Center – which is barely six years old – is a new and experimental departure in international education. Its underlying purpose is to increase understanding among nations through cross-cultural interchange in an academic setting. The people who come here to study and participate in the various Center programs also undertake an obligation to engage in cross-cultural activity, to learn more about one another. In this way, we hope over the years to make some contribution to the development of a more peaceful world.

You should understand that the Center itself does not grant degrees and it has no faculty. Those who come here under grants actually study at the University under members of the university faculty, and the degrees they earn are awarded by the university.

The Center itself is the device by which participants are invited, by which special programs are developed and by which cross-cultural interchange is facilitated.

The Center, then, is a cooperative effort. The United States Congress appropriates the operating funds – almost six million dollars a year and the University of Hawaii provides the academic instruction.

This past academic year people have come to the Center from 30 countries in Asia and the Pacific as well as from the United States. The students who come to the Center are chosen on a basis of roughly two Asians to one American – the idea, of course, being interchange among cultures.

Geographically, the activities of the Center extend to as far as Afghanistan and include all of Asia except for Communist China and Russia.

Now, then, a few words about how the Center is organized. We start with three main institutes – the Institute of Advanced Projects, the Institute of Student Interchange and my own Institute of Technical Interchange.

In Advanced Projects we have usually 40 to 50 senior scholars who come here for varying periods of time to write, to conduct research and to participate in seminars.

In the Institute of Student Interchange we have approximately 600 students who primarily work for master's degrees.

In addition to the institutes we also have the East-West Center library which is developing a superb Asia collection. And we also have the Press, which imports and exports books between America and Asia and

[1]Vice Chancellor, Institute for Technical Interchange, East-West Center

also occasionally publishes the work of senior scholars in residence here.

Detailed information about these activities can be found in the literature which has been given to you. I would like now to discuss the functions of my own Institute, which, with the university's college of tropical agriculture, is co-sponsoring this weed control program.

My institute – called ITI for short – provides approximately 350 grants a year for practical non-degree technical training in five major fields. These are government and administration, women's career development, health and medical technology, education and communication and economic development.

The programs under these headings are designed for the interchanging of skills. The guideline is "interchange". We do not, let me emphasize, approach this in the spirit of Americans training others in a one-way situation. The flow is in both directions. Asians, Pacific Islanders, Americans or Europeans – whoever has anything useful or better to share – is welcomed to our programs.

By the same token, no one is required to accept what is offered by others. No one flunks out, just so long as they are sincere in their participation.

I hope that you will participate in this weed control program on this basis – with the idea that information must flow in two directions.

Now, we have two major kinds of training programs. One kind is the Hawaii-based, such as the one in which you are involved, and can run anywhere from a few days to an entire year.

The other type of program is field training. These programs are held away from Hawaii, either in Asia or the Pacific. Suppose there is a particular problem to be solved. We look for an area located nearest to the center of the problem and the population affected. Then ITI selects a team of qualified individuals to mount the training program in the field.

These teams may not even have Americans on them; or they may be mixed.

For example, if we should like to hold a field training program in weed control next year, let us say in Bogor, Indonesia, we would select a team and send it there. Individuals interested in weed control or involved in it would be invited to come to Bogor to participate.

The advantage of holding such a program in Bogor or Bangkok or wherever a particular problem exists is that more people can participate because it is less expensive than bringing people to Hawaii.

In closing, I wish to call your attention to the presence at this program of representatives of commercial firms. This is something new and, I am sure, of potentially great benefit.

I hope that the commercial representatives will share their ideas and reactions freely with us – and, who knows, perhaps out of this program will come a super weed-killer.

Good luck to all of you. While in Hawaii, spend some time enjoying our aloha spirit and our hospitality. But I have to give you one word of caution: please do not take off and go swimming during the hours when activities are scheduled. This is the time when the sharks are the most vicious – so keep the schedule during these critical hours.

THE COLLEGE OF TROPICAL AGRICULTURE AS AN INTERNATIONAL RESEARCH AND TRAINING CENTER

C. Peairs Wilson[1]

There is, today, a world food crisis in the sense that a large proportion of the world's population is afflicted with hunger, malnutrition and the threat of starvation. There is every indication that the crisis will become worse in the decades ahead. Robert Ewell has said, "It seems unlikely that stable governments can be maintained in countries where a large part of the population is starving. This is the biggest, most fundamental and most nearly insoluble problem that has ever confronted the human race."

President Johnson has said, "Hunger poisons the mind. It saps the body. It destroys hope. It is the natural enemy of every man on earth. I propose that the United States lead the world on a war against hunger."

The current and evolving world food crises must be attacked both from the standpoint of increasing the rate of food production. The most promising means of achieving increased food production is through research and education to develop and put into use improved agricultural technology.

Most of the agricultural research in this world has been conducted in the temperate zones – in North America, Europe, Japan, Australia and New Zealand. Most of the hungry people of the world are in the tropical areas of the world – Southern Asia, Africa, Latin America. And, it is in the areas where the people are that most of the increase in food production must take place. To be sure there will continue to be shipments of food from certain temperate zone areas to tropical areas but under the best of circumstances the volume will be small in relation to the total need. What is desperately needed is to make the tropical areas of the world more productive. This means that there must be increased emphasis and increased effectiveness of research and education in the tropics.

It seems to me that we have been terribly slow to recognize the fact that it is not possible to transfer directly the temperate zone agricultural technology to the tropics and make it work. Even though that fact is now generally accepted, we are terribly slow in doing anything about it. Secretary Freeman said two years ago: "First there is need for more applied research – taking what is known and what is available in developed areas. And, second, there needs to be more specialized tropical research." He also said, "I'm speaking of the needs for applied research – research to adapt varieties of important staple food crops to local environments, research to identify and develop control measures for tropical insects and diseases." Dr. Byron Shaw said: "We must start from scratch, in many areas, to learn the secrets of tropical and sub-tropical soils and the demands of exotic crops. F. F. Hill, Ford Foundation said: "It is my considered view that a major roadblock to progress toward increased food production in developing regions of the world has been the lack of substantially improved production technology suitable for use in the tropics and sub-tropics."

The College of Tropical Agriculture, University of Hawaii, is one of the two agricultural colleges in the United States located in the tropics. The other is Puerto Rico. The College of Tropical Agriculture here at the University of Hawaii is not as

1 Dean and Director, College of Tropical Agriculture, University of Hawaii

large or as old, or as prestigious as the Agricultural Colleges of Cornell or Wisconsin or Minnesota but I submit it has more knowledge of Tropical Soils, Tropical Crops, Tropical Entomology, Tropical Plant Pathology, than all three of them put together! Those institutions, located as near to the Arctic Circle as to the Tropic of Cancer, must find it difficult and expensive to simulate tropical conditions in a biotron. We in Hawaii have all the outdoors to work in. It is known that, in spite of the relatively small geographical area of our Islands, our soils are representative of hundreds of thousands of square miles of soils throughout the tropics. I say this with some degree of confidence even though some soils experts in USDA say Hawaiian soils must be different because they are so productive. I'll tell you why they are productive – it is because we understand them and this permits superior management. It is management that makes them productive. Many of our crops are the same as in other tropical regions of the world. Varieties and hybrids adapted to Hawaii's soils, rainfall, temperature, day-length, light intensity and resistance to our insects and diseases are more likely to be adapted to other areas in the tropics than varieties and hybrids adapted to the mid-West. We are confident that investment in research in tropical agriculture by international, national and commercial agencies will be less costly and more meaningful than similar investments at mainland institutions. Although President Johnson has said it is our Nation's policy to lead the world in a war on hunger and although the Congress has passed the Food for Peace Act authorizing research in tropical and sub-tropical agriculture, no funds have been appropriated nor has the College of Tropical Agriculture been asked to participate in planning such research.

Up to this point I have been speaking primarily of research in Tropical Agriculture at the University of Hawaii. I would like to say something about training and education.

Not only does the College of Tropical Agriculture have an environment similar to the areas needing research, we also have other attributes which favor Hawaii as a training and education base. We have geographical proximity. Hawaii is 2500 miles closer than the West Coast and 6000 miles closer than the Atlantic Seaboard.

In addition, Hawaii has a cultural proximity not even approached by any part of the mainland. More than half our population looks to Asia and the Pacific rather than to Europe as the place of their ancestral origin. There is, in Hawaii, a measure of interest, concern and empathy for the people of Asia and the Pacific not found in other parts of the United States.

The College of Tropical Agriculture has 130 graduate and undergraduate students from foreign lands. Most of these students come from Southeast Asia and the Pacific. About 90 are graduate students pursuing the Master's degree or Ph.D. degree. A significant proportion of these students come on East-West Center grants. These students hopefully will complete their degrees and return to their home-land to contribute to the agricultural development of their country.

An increasing proportion of the undergraduate and graduate students from Hawaii and the mainland are preparing for careers in international agriculture. In the past the United States has staffed its international agricultural programs with personnel who were not initially trained for that purpose. They were trained as agriculturists for work in their local state. If my analysis of the situation is correct, we will need a large number of agriculturists over a long period of years ahead. This suggests that we should be training students for careers in international agriculture. It suggests that heavy emphasis should be on Tropical Agriculture. Hence, we are experimenting with techniques and programs that will motivate students for such careers and provide educational experiences that will be somewhat typical of the kinds of situations that will face them on their job.

In addition to the degree programs described above, our faculty is also engaged in non-degree short-course training programs in cooperation with the Institute for Technical Interchange of the East-West Center. In some cases the trainees are brought to Hawaii and in other cases our faculty is sent out to other countries for the training program.

Finally, our faculty participates in training programs for U. S. personnel going abroad. This includes Peace Corps Volunteers, AID personnel and others. Many individuals and small groups from USDA, AID, Foundations, U. S. Universities and others stop by for a few hours to a few days to learn something about Tropical Agriculture.

We feel that in the past the opportunity to use Hawaii as a base for research and education in tropical agriculture has not been fully exploited. Our tropical environment, our research base, our professional staff and facilities, our location at the crossroads of the Pacific all enhance the possibility of making greater use of Hawaii as a research and education base. This particular conference will hopefully lead to others. We think we have something on weed control to offer to our visitors; we think we have something to learn from our visitors. We think it can be a valuable contribution to agricultural development.

I suppose that all the activities that are undertaken to produce food and fiber crops, none are more costly than eliminating or controlling unwanted plants that compete with crop plants for water, nutrients and sunlight. Anything we can do to improve the technology of weed control will reduce costs and increase productivity of economic crops. In the two weeks we will be together I hope we may learn from each other. This will have made it a successful conference.

PRESENT AND FUTURE WEED RESEARCH PROGRAMS OF THE COLLEGE OF TROPICAL AGRICULTURE

G. Donald Sherman[1]

Present research in weed control at the College of Tropical Agriculture of the University of Hawaii includes studies in both basic and applied fields. It is becoming more and more imperative that weed research be expanded in Hawaii. First the need is due to the increased costs and the diminishing supply of farm labor which practically mandates that methods of weed control be developed to reduce labor input. Weed control by mechanical, chemical and biological methods offers a solution to this problem, and our programs emphasize the development of research in these areas.

Secondly, our present and planned research programs will emphasize our role in developing control methods which can be applied and utilized in the tropical regions of the world. Our findings can be applied over much of the tropics and especially in areas where food production is a serious problem and where population density is very high.

It is not necessary to remind you that a weed is an unwanted plant. Its survival is due to its capacity to compete. One of the remarkable examples of a weed's competitive capability was clearly demonstrated in an experiment where radioactive phosphorus was applied to a pot containing one of Hawaii's bauxitic soils with a legume plant and a common noxious weed plant growing in it. The latter was capable of taking up the radioactive phosphorus and the legume was only able to take up a very small fraction of the radioactive phosphorus. This is only one example of a weed's adaptation for survival and there are many others such as prolific seed production with or without seed coating for protection to prolong its germination life span. These characteristics and many others provide a means of competitive survival.

The research in Hawaii can be divided into six areas, namely: (1) screening of chemicals to establish and identify effective herbicides for tropical weed plants and to determine their tolerance to herbicides under our tropical climatic conditions; (2) basic research in the nature of the physiological action of herbicides on plants; (3) development of methods of application of herbicides; (4) crop and plant management systems to improve the desired plants' competitive growth capacity; (5) basic research in the decomposition, absorption and movement of herbicides in soils of different mineralogical composition which are commonly found in tropical regions; and, (6) biological control through introduction of natural and restricted pests of weed plants. These programs are conducted in the fields of agronomy, horticulture, plant physiology, botany, engineering, biochemistry, and entomology.

In the screening and identification of chemical herbicides the agronomists and horticulturists have developed a profitable joint cooperative program with Oregon State University. In this program chemicals are tested for their herbicidal properties for control of a large number of weed plants common to tropical regions. Their herbicidal properties are identified and the plant tolerance limits are determined. Another section of this program involves the Food and Drug clearance of these materials so that chemicals providing control can be recommended to our farmers.

The basic research program in physiological actions of herbicides in plants needs a greater stimulation in its activities. The work to date has been limited to a few well established herbicides.

The agronomists of our College have placed considerable emphasis on the development of methods of application of herbicides to first reduce the costs and secondly to reclaim rough lands for crop production, pasture development, and improvement of forest species composition and reforestation. The utilization of aerial application of herbicides for brush clearance or rough land has been one of our major developments in this program.

Agronomic management of a crop or desired plant can lead to a control of some weed pests. A good example of this is control of crab grass in lawns by frequent application of nitrogen fertilizer and withholding phosphorus fertilizer. The latter enhances the competitive capability of crab grass. Of course, the elimination of crab grass will be hastened with the application of a herbicide in this management practice.

Important differences of the action of herbicides have been observed on soils of different mineralogical composition. There is a wider range of mineral composition in the soils common to the tropical regions due to the major role mineral decomposition and leaching play in tropical soil formation. Tropical soils are characterized by whole series of secondary minerals ranging from hydrous micas, the 2:1 swelling aluminosilicate clay minerals, minerals of the kaolin group, amorphus silicate clay and oxide minerals, and the crystalline oxides of aluminum, iron, and titanium. Because of the intensive weathering and strong influence of secondary mineral development in soil formation, parent material plays a very minor role in soil properties. Likewise the dominance of secondary mineral constituents has lessened the role that organic matter plays in overall soil properties. Hawaii has a wide range of soils common to vast areas of the tropics as soils are formed under 5 to 500 inches of annual rainfall. In addition a wide range of tropical soil development occurs because of the range in time during which materials have been exposed to the soil forming process:--recent volcanic deposition to old earth surfaces of 9 to 10 million years. Studies are being made on the adsorption, movement, and decomposition of pesticide chemicals in typical mineral soils common to tropical regions. Herbicides are included in these studies.

Hawaii has utilized the introduction of insects to control lantana and cacti with very successful results. Such introduction requires extensive studies of both the insect and the host plant so as to ascertain the limits of the activities of the introduced insect.

The future weed research program will take advantage of the unique position of Hawaii as a natural laboratory. The islands possess within distances of 200 miles climatic zones and soil types common to vast areas of the tropical regions. It has a broad range of economic and exotic plants which are common to a whole range of tropical regions of the world. Since a wide range of environmental conditions occurs within a compact area of Hawaii, our research program will be expanded to conduct research on weed control for the entire tropical world. The islands should not only become the center for research for weed control for the tropical regions but also the research center for tropical agriculture. This center should also

[1]Associate Director, Hawaii Agricultural Experiment Station, College of Tropical Agriculture, University of Hawaii.

offer college training at both the undergraduate and graduate levels. In addition both industrial and technical training should be offered so as to improve the productive capacity of agriculture in the tropical world.

One cannot overemphasize the importance of a tropical research center to the field of food production in the tropics. As a result of research at the Hawaii Agricultural Experiment Station the methodology was developed for agricultural crop management and the adoption of these methods has raised the yields of the economic crops to among the highest in the world. In the past 20 years yields have been doubled for such crops as sugar cane, coffee, pineapples, corn and many other crops. If the technology developed in Hawaii were applied in other areas of the tropics it would be safe to say a 50 per cent increase in the world food supply could be envisioned.

In conclusion it is research and leadership which will increase the productive capacity of tropical agriculture, be it weed control, fertility management or crop improvement A research facility in the Hawaiian Islands dedicated to the solution of the problems would make a real contribution to social, economic, and scientific improvement of life in the tropics.

THE IMPORTANCE OF WEED CONTROL IN TROPICAL AND SUB–TROPICAL AGRICULTURE

William R. Furtick[1]

Although weed control is basic to all agriculture, most of the research and nearly all of the adoption of specialized implements and chemicals for weed control has been limited to the temperate zone of Europe, North America and similar regions until very recently. Weed problems under temperate zone agriculture are a major factor in limiting the production of food, feed and fiber crops and much of the common agricultural production practices have been based on the need for weed control. In order to effectively utilize the wide array of new agricultural technology developed by agricultural research scientists it has been necessary to utilize vastly improved weed control practices. Unless weed competition is eliminated, it is not possible to obtain the full yield potential of newly developed crop varieties with high quality, high yielding capability and disease resistance which are designed for production under high levels of fertility, adequate water from irrigation or rainfall and which are kept free of insect pests with insecticides. Although the competition from weeds has been recognized as an important problem by farmers since the beginning of agriculture, it has only been since World War II that a concentrated effort has been made to thoroughly determine the importance of weed control in agricultural production in the temperate zone areas. As a new generation of weed control research scientists has arisen to take their place among the many diverse agricultural specialists, they have found that weeds were a much more important factor limiting food production and utilization of new technology than had been generally realized by agronomists. As a wide array of new implements and chemicals were developed to bring about precise and selective removal of weeds in most temperate zone crops, the results were quickly recognized by commercial farmers and there has been a rapid adoption of the new technology during the past ten years in Europe and North America. This is most readily illustrated by the fact that ten years ago herbicides represented a relatively small percent of the total sales for the world pesticide industry. During this ten year period the sales growth of herbicides has been enormous in relation to the growth of insecticides and fungicides which has also been substantial. The degree of recognition farmers have given the weed control field is illustrated by the fact that herbicides surpassed insecticides in importance in the pesticide industry during the past year. This occurred in spite of the fact that in the period since the close of World War II there has been a dramatic growth in the use of organic insecticides, not only in the temperate zone of North America and Europe, but also on a world-wide basis. There has also been a very large increase in the use of fungicides and other disease control agents particularly in the tropical and semi-tropical areas. The use of insecticides and fungicides has become a standard practice even in many areas of so-called subsistence agriculture in the tropics as well as temperate zone agricultural regions during the past ten years. In spite of this general acceptance of insecticides and fungicides in the tropics, the use of herbicides and specialized weed control equipment in tropical regions has not paralleled the rapid acceptance of the other pesticides. It has only been in the past two or three years that any appreciable quantity of herbicides has been marketed in the tropical regions. The use of herbicides still represents only a fractional quantity compared to insecticides and fungicides. This lack of widespread use has no relationship to the problems weeds represent under tropical and semi-tropical agricultural conditions.

The rather substantial research effort on the value of weed control in temperate zone crops has resulted in a wealth of data on the losses to agriculture as a result of weed encroachment. Unfortunately there has not been this same level of effort in the tropical and semi-tropical areas and it is not possible to quote a wide range of studies that indicate weeds represent a given loss to tropical and semi-tropical agriculture. All of us who have been associated with weed control in temperate climate areas and have also had experience in tropical and semi-tropical agriculture, recognize that weeds play a much more important role in limiting crop production under tropical and semi-tropical conditions than in temperate zone climates. My reason for dwelling on the importance of weed control in the temperate zone is to dramatize the enormous importance of weed control in tropical agriculture where the number and diversity of weed problems are much greater than under temperate zone conditions and weeds present a problem over a much longer period of the year or in many types of tropics on a full year basis. If the losses from weeds under temperate zone conditions can be considered enormous, there is probably no good way of fully expressing the total importance in tropical and semi-tropical agriculture other than to say it is frequently limiting effective agricultural production.

[1]Professor, Farm Crops Department, Oregon State University and Director, Oregon State University/AID Research Contract "Development of Weed Control in Less Developed Countries."

It is impossible to generalize the problems weeds present in tropical and semi-tropical agriculture because you are not talking about a single type of agriculture. As you all readily realize, you cannot deal with the tropics as an entity from an agricultural standpoint because there is an unbelievable diversity in the climates, soils, topography, cultural traditions and economic resources involved in the tropic regions. The diversity is so much greater than the temperate zone that they cannot even be considered on a similar basis. Perhaps one of the most discouraging aspects of trying to clearly outline the problems of weeds in tropical and semi-tropical agriculture is that the only thing that exceeds the diversity of the problems under tropical conditions is the void of information available for many of the tropical production regions.

There is general recognition in the temperate zone regions that the research efforts in weed control have been completely inadequate to even partially assess the losses, identify the problems and demonstrate the value of solutions for the weed problems of temperate zone agriculture. The weed research scientists in North America can most readily be identified through their membership in the Weed Science Society of America which is a professional organization of weed research workers in the United States and Canada with some membership from other areas of the world. There are over 1000 members of this Society that are working in the United States and Canada. Similar societies in Europe have at least an additional 1000 members. When you add to these workers in the Soviet Union and Eastern Europe, New Zealand and the temperate zone areas of Australia and other temperate zone regions, it would appear safe to assume there are between 3000 and 5000 scientifically trained staff working in the weed control field for the temperate zone regions. This Pacific-Asian Conference represents a majority of the weed control workers in the tropical regions outside of Latin America and Africa. I have spent substantial periods in the tropical areas of Latin America and know probably all of the weed research staff in tropical South America. Adding all the tropical regions together perhaps 100 trained professionals in weed science for the tropics would be an optimistic number. If the assumption is correct that the efforts devoted to weed science in the temperate zone have been far too small to accurately assess the problem and bring about adequate solutions in spite of the efforts of several thousand trained professionals, then it is readily apparent that little information is available in the tropical regions of the world which have much more serious weed problems with much greater diversity of climates, crops, weeds, and cultures. The 100 or less workers could hardly make a start in assessing the problem.

With this background let us examine, in more detail, the importance of weed control in tropic and sub-tropic agriculture. Perhaps the biggest single factor in the importance in weed control in tropic and sub-tropic regions is the fact that weeds are such a major factor in limiting crop production. This assumes enormous importance with the present pending world food crisis which is particularly evident in those nations which lie in the tropics. In order to adequately discuss the importance of weed control, it must be emphasized that although weed control is basic to agricultural production it is an intricately related part of agricultural production technology in that weed control alone will not solve the problems of any segment of agriculture but without weed control agricultural production problems cannot readily be solved either. This is to say, that weed control and all other improved agricultural technology must work together as intricately inter-related parts of a whole in order to bring about optimum production. Crop yield will be maximum only when all production factors are optimum. The basic production factors in agriculture can be summarized as crop variety, fertilizer types and rates, soil conditions, water, spacing, climatic factors, disease and insect control, and weed control. Now, although I am listing weed control last, it does not indicate its relative importance; since without weed control optimum conditions for any one of the other factors required for maximum production would have little effect in improving yield. In fact, without weed control improvement in any of the other factors might frequently cause yield reduction. This can most readily be demonstrated in most tropical conditions where under heavy weed pressure increased fertilization of crops without adequate weed control may bring substantial yield reductions because the weeds respond readily to the fertilizer and their competition with the crop is substantially increased and more than offsets the improved conditions from added fertility. So far there has been little effort devoted to developing varieties that couple high yield capacity with their ability to compete with weeds. Very frequently you have the choice of crop varieties with high yield potential under weed-free conditions that may be relatively low yielding if they must compete with weeds compared to other varieties which may be the best yielding variety because they are more competitive with weeds, but are completely inferior under weed-free conditions. Often introduction of new high yielding varieties developed in weed-free nurseries will result in yield reduction under commercial conditions because they are less competitive with weeds than the older varieties with less inherent yield potential. The same illustrations could be utilized with supplemental irrigation, closer row spacing or higher plant populations, introduction of disease resistant plants or any of the other production factors.

Perhaps the best illustration of these inter-relationships can be found with rice, particularly upland rice in which there is no weed control through flooding. This can be clearly illustrated by the following statement from the Philippine International Rice Research Institute's 1965 Annual Report which says on page 227: "An important reason for low yields of most upland rice is the absence of effective low-cost weed control. A few varieties will produce yields nearly equal to those of flooded rice but many of the short statured or low tillering types will be outgrown and overtopped by weeds especially under high fertility conditions. Hand weeding is effective and widely practiced but the cost of human labor is high, and the rice production returns are low. Mechanical methods are used effectively only in course textured soils and are seldom good enough to permit maximum yields. Effective chemical measures could greatly increase the return to labor and management and entirely change the outlook for upland rice." In the same Annual Report the problem was illustrated where three herbicides were compared with hand weeding and no weeding on a drilled planting of rice. Without any weeding the average yield was 575 kilograms of grain per hectare while with hand weeding the yield was 3,943 kilograms per hectare or a gain of three and one-half times. The best herbicide treatment gave a yield of 3,500 kilograms per hectare or almost the equivalent of hand weeding. Although it is possible to find a number of research results which indicate that through the use of hand weeding or the introduction of herbicides under tropical agricultural conditions, dramatic yield increases can be obtained, ve
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obtained, very little data are available. I challenge all of you here today to help determine the role of weed control in the tropics. One of your prime considerations in the future should be to determine the yield potential of tropical crops made possible by the introduction of effective weed control measures and coupling them with improvements in all of the other production factors. To put this more clearly: if you can control the weeds satisfactorily with chemicals or improved mechanical means, what can be done under the weed-free environment to utilize high yielding varieties under optimum fertility and optimum irrigation, soil management, disease control and insect control practices? These are the answers that I have been unable to find in my travels in many tropical areas. Although these answers on production potential are enormously important in the long term problem of solving the food needs of the tropical areas, great improvements in production can be demonstrated through improved weed control without bringing all other production factors up to optimum. Yield increases resulting from improved weed control alone would be enough to more than solve the current food needs and bring about an agricultural surplus production in many tropical areas.

It must be recognized that improving the weed control in many tropical areas is fraught with many difficulties. We have little knowledge of problems that might be created if major adoption of herbicides or mechanization for weed control were to occur in most areas. Some of the potential problems can be listed, but their real importance is only speculation. The following are some of the major questions I would like to have you consider in determining the implications of weed control in the tropics:

1. Can the modern herbicides and equipment be effectively introduced into primitive or subsistence agriculture and what effect would their use have on land tenure, and commercialization of agriculture?
2. What are the erosion problems that a weed-free environment would create in row or plantation crop production in the humid tropics?
3. What changes in basic agricultural practices could or would have to be made in a weed-free environment?
4. Would complete weed control capability make changes possible in the slash-burn subsistence agricultural practices of some humid tropics?
5. Can methods be worked out to prevent disastrous erosion, maintain nutrient cycling and soil quality on a permanent basis by a planned manipulation of crop ecology which may be accomplished with selective chemicals?
6. What would be the impact on the local community if herbicides and mechanization eliminated much of the need for hand labor?
7. How would increased production or changes in the cost of production of various crops affect the local economy?
8. How would increased food supplies affect population trends?
9. What effect would the reduced need for labor have on the individual family including desire for children and family social structure?

Although the questions raised cover broad areas of agronomy, economics and anthropology, they are still basic to the problem. I feel confident that the major question is not "will herbicides and mechanization become a major factor in the tropics" but when and how rapidly will this occur. My guess is that the speed will be much greater than will permit adequate research on any of the questions I have raised. I hope this conference can stimulate action that will help increase the rate at which needed answers are obtained.

I know the broad questions that have just been raised are the hardest ones to answer. This does not mean that they are the only ones that must be approached, as many technical problems of weed control must be solved before the broad questions become involved. In some regards I may have sounded as if modern methods are already available to solve all weed problems of the tropics. Actually only a bare start has been made in this direction. However, I have had a chance to follow very closely the recent discoveries in herbicides, equipment and basic research and I feel solutions to most of the major weed problems of the tropics can be rapidly found.

The almost total substitution of chemicals for labor in weed control on sugar cane and pineapple in Hawaii the past few years illustrates this probability.

Products already known will selectively remove most annual weeds in nearly every commercial crop. The biggest unsolved problems are some of the serious perennial weeds, particularly nutsedges, *Cyperus sp.* and many perennial grasses. Recent discoveries may soon solve these problems. Extensive research will be necessary to adapt these new discoveries to the variety of conditions found in the tropics. The specific problems and some of the promising solutions in the various crops will be explored in detail during the conference. I hope this will stimulate an increased effort at solving the weed problems of the tropics.

A PRACTICAL APPROACH TO WEED CONTROL IN THE SOUTH WEST PACIFIC

A. H. Cates[1]

The more technical we become in the advanced countries, the wider grows the gap between ourselves and the peasant farmer in the under-developed regions.

It has been claimed in Palestine, that agriculture has progressed in the course of 40 years from methods practically identical with those practised in the days of the Bible to modern farming based on intensification, diversification, mechanisation and specialization.

Our system of agriculture in the Pacific Island territories, until 10 years ago, with some notable exceptions, could certainly be described as something from the Old Testament. Perhaps later, one section of it will be known as the "cane knife period".

Within a decade tremendous strides have been made with the introduction of agricultural chemicals. And here lies a pitfall. Many planters, seeing the almost miraculous effects of herbicides, are assuming they are the be-all and end-all of their weed problems. No thought is given to the careful husbandry which still is a 'must' even with herbicides, if any sort of long-term results are to be obtained.

[1]Sales Director, Lane's PTY. Limited, Suva, Fiji

The progress from primitive to intensive agriculture must always be headed by agricultural research. This research, however, will remain a dead letter unless appropriate methods for translating the results obtained into agricultural practice are developed.

There are few things more incongruous than having an up-to-date experimental station surrounded by a primitive agricultural community. While there is every justification for the experiment station to be one or two jumps ahead in equipment and method when compared with those used by the farming community it is designed to serve, it is futile if the gap between the two continues to widen instead of becoming narrower.

Close links between research and the forming community are essential, and this is where the extension worker becomes the logical link. He is the one who first must try out new ideas, resulting from research, under normal farming practice, and it is he who brings the problems of the farmer to the notice of the research worker.

Both the research worker and the extension officer may be fully qualified and excellent technical men, but both must be on guard constantly not to let their superior knowledge, or their desire to improve this knowledge, interfere with the work they are designated to carry out, i.e. to get their ideas across to a peasant farmer in the simple type of language he understands.

It is a fact in agriculture, as in all sciences, over-education can be almost as big a danger as under-education.

Let it also be noted no-one ever loses dignity by having dirty hands. It can well be that research officers and extension workers, considering themselves technical men, are loathe to get out in the field to demonstrate their knowledge to farmers who understand little else but practical demonstrations.

The average farmer or planter in the South Pacific area knows little about active ingredients, or the difference between hormone weedkillers, pre-plant, pre-emergence and post emergence herbicides. These must be demonstrated and explained to him in a simple fashion. The farmer should also be familiar with measurements and amounts of herbicide per gallon, in order for him to have confidence in the manner in which the chemical works.

To this end, in Fiji, Mr. T. L. Mune, Weeds Officer (now retired) with the Department of Agriculture devised the following local herbicide measures. The measure table was published widely through the Department of Agriculture, and now the majority of our farming population is aware of it.

1 fluid ounce	1 McCallum's whisky bottle top
2 fluid ounces	Capstan or Champion 2 oz tobacco tin filled up to the first ring
4 fluid ounces	Craven A Curly Cut 2 oz tobacco tin
5 fluid ounces	State Express 2 oz tobacco tin
10 fluid ounces	50 Cigarette tin
3 gallons of water	1 Rega or other large knapsack sprayer
2 gallons of water	1 Standard small knapsack sprayer
40 gallons per acre	14 large sprayers full
40 gallons per acre	20 small sprayers full
80 gallons per acre	27 large sprayers full
80 gallons per acre	40 small sprayers full

Trade formulations of the hormone weedkillers containing 3.6 lb of acid equivalent per gallon and applied as a dilute solution in 80 gallons of water per acre, are usually mixed from the following measures:

Fluid ounces of formulation diluted in 3 gallons water	lb acid per acre
1	0.6
2	1.2
3	1.8
4	2.4
6	3.6

These mixtures may work out a little more than required, but as far as farmers are concerned they are all that is wanted and are therefore satisfactory. Other territories could well follow this lead giving attention to simple, familiar types of measures with which their people are well acquainted.

One of the major problems today is the vast number of new products appearing on the market. This applies particularly to the pre-emergence and post-emergence groups, as well as foliar and soil treatments.

In many instances, timing of application and soil conditions as well as rainfall play a major part in the effective use of these products. Unless the farmer understands all facets of these types of applications it is useless for him to attempt their use.

It should be remembered also, seldom has he the equipment required to incorporate many of these materials according to instructions from the herbicide manufacturer. Here again, practical demonstrations of these chemicals, and explanations in a simple, easy language, given on the farm itself, are the best methods of teaching the farmer.

A most important factor in the instruction to the formula is the use of a sprayer whatever its type. Visual aids, as well as practical demonstrations, are most helpful in this type of instruction. Quantity per acre etc. must be explained and demonstrated thoroughly.

In the Pacific area three types of sprayers are most commonly used:

The Knapsack Sprayer which is designed to meet the requirements of the small farmer. These machines are strongly made, simple to operate, and will give good service for years if properly maintained.

The Misting Machine which is motorised and which is excellent for the more sophisticated farmer. To get the best out of these machines, proper instruction on their use is essential. They are of immense value on hilly country, but at the same time the machines should always be operated downhill.

The Power Sprayer which is tractor mounted is a machine used mainly on large holdings and plantations by labour under supervision.

It should be remembered that proper selection and then proper use of a sprayer is just as essential as the proper selection of the herbicide which is to be applied.

Areas of high rainfall and high humidity, have prolific growth rates of weeds. Problems of their control are largely tied up with the long protracted seeding period not governed by well-defined seasons. Short, sudden downfalls of tropical rain can nullify the effect of a recently sprayed area.

The choice of a particular herbicide which will stand up to these conditions, plus the use of a suitable surfactant or wetting agent, is essential under these conditions. Water alone is a poor wetting agent. This is a problem for the research worker and extension officer for very little work has been done to date.

I would now like to touch briefly on some of the major crops of the South West Pacific in relation to their weed problems.

COCONUTS

Coconuts are grown under the more favourable conditions of soil and climate, and they do not present severe competition to scrub type undergrowth. Consequently, the weeds of coconut plantations are many and varied according usually to the previous management history of the plantation.

In badly managed situations, guava grows to the exclusion of other weeds. In the areas overgrazed by goats, fern (which is quite unpalatable to stock) becomes completely dominant. In plantations where grazing by cattle and goats used as weeders has occurred, lantana, guava seedlings, hibiscus burr, blue rat's tail, kaumoce, mile-a-minute, etc. are all problems.

With the exception of fern, all other weeds listed are hormone sensitive. It is considered the objective of grassing the coconut plantations and producing meat from them as well as copra, can be achieved by the following:

a. Removing the standing cover of weeds by the use of hormones.
b. Introducing grasses as soon as the weed top growth dies and admits sufficient light.
c. Fencing into areas so that rotational grazing may be carried out. Over-grazing should at all times be avoided.
d. Maintenance spraying to control the regeneration of difficult weeds such as guava and to prevent the ingress of other weeds.

This technique must be demonstrated before progress is made.

It is surprising to note, the planters who have quite large numbers of cattle, and who are so ill-informed about the ecology of grass and grass animal relationships, when an understanding of these principles is essential if their objective is to be obtained.

With all the technical information at the planter's disposal today, it is still amazing to find the number who expect to apply a hormone weedkiller and see the results the following day.

This lack of understanding of the basic principles of weed control is widespread right throughout the South West Pacific. Many planters still feel that weedicides should be the complete solution in themselves to their weed problems. No thought is given to plantation management and good farming to which weedkillers are purely an adjunct.

The coconut industry is second only to sugar in Fiji's annual agricultural wealth, yet no crop has had such a constant need for more efficient weed control.

The history of the coconut industry is a history of ineffective methods of weed control throughout its development.

Before the land was settled it was in heavy bush or tall reeds. When the bush was cut difficulty was experienced in obtaining a clean burn because of the high rainfall. This added to the trials of the planter, as poor burns meant great masses of logs and stumps giving protection to secondary growth and weeds. This situation prevailed for the first five to ten years of the young plantations development.

It was little better where reeds dominated the land, for as fast as topgrowth was removed, the roots sent up new shoots. Until the last decade there was no improvement in plantation weeding. The cane knife was the chief weeding tool and over the years hundreds of thousands of man-hours have been wasted in once or twice a year slashing.

This treatment, at its best, was only a means of removing unsightly top-growth, it had no effect on the roots of the weeds. To many of the weeds it appeared to be actually beneficial and it encouraged their spread and density.

Many planters became discouraged and considered money spent on weeding as money lost. and slowly reduced their weed control operations to slashing every two or three years. This attitude towards weed control has passed from father to son, and weeds have become accepted as part of the plantation. This is the greatest problem to overcome in the weeding of plantations, and planters must be persuaded that they cannot afford NOT to weed.

No methods of weed control can be successful without the support of a regular weeding programe, involving the general management of the plantation.

Weed control is an important part of plantation work, and must be planned with care, making full use of the most effective methods, directed at the destruction of the growing weed, and the weed seeds in the soil.

SUGAR CANE

This is the country's biggest income-earner, as well as being the best organized and technically served industry in Fiji.

The important weeds in sugar cane are: Ipomoea, Kaumoce, Wild Passionfruit, Prickly Cucumber and Johnson's Grass. In many cane areas it is Johnson Grass which poses the most serious problem.

Johnson Grass is widely known throughout the Pacific. It is controlled in some areas with the use of Dowpon.

Pre-emergent control is practised on S.P.S.M. estates only, using 2,4-D Ester or 2,4,5-T – sometimes a mixture of both.

None of the substituted Ureas such as Monuron, Diuron etc. are used owing to cost.

No individual farmer in Fiji uses preplanting or pre-emergent methods, although a large percentage do use post-emergent treatment using mainly 2,4-D Ester. Post-emergent as well as pre-emergent procedures are followed on estates.

NUT GRASS

This weed is kept under control in young cane on the estates with 2,4-D Ester.

During the last few years the number and variety of chemical herbicides for use in cane have shown a rapid expansion. The possible applications of some of the more recently available have not yet been explored due mainly to lack of S.P.S.M. staff and poor prices received for sugar.

However, it seems very likely that these, and others yet to come, will provide the answers to many weeds exhibiting resistance to present chemical herbicides.

Some of the newer products will doubtless provide more efficient means of control of weeds which are, at present, attacked with well-known chemicals.

Although the new materials are, on the whole, more expensive per pound than the older types at present in use, as demand for the new products increases and markets grow, it can be expected that costs will be reduced.

Another point to consider, is many of the newer herbicides provide longer lasting control than do the older materials, and despite higher costs per pound, are actually cheaper in use because of the lesser number of applications or quantities of material required for the same result.

BANANAS

It has been rightly stated on many occasions that bananas and weeds do not mix. Weed infestations are particularly serious for the banana plant because of its shallow rooting habit which suffers severely with weed competition.

Until recently banana production came from "ranching" (unmanaged plantings) rather than from farming. However, over the last 3 years in Tonga, Samoa and Fiji plantation farming is being practised.

In Samoa arsenic is used extensively for weeding banana plantations. It is used in Tonga to a limited extent and not at all in Fiji as a result of a mutual agreement between the Department of Agriculture and importers.

Arsenic is still the cheapest general purpose weedicide for use in banana plantations, giving quick, spectacular results which appeal to the farmer in areas where it is used.

The main objection to arsenic is its danger to humans and stock. Cases of cattle poisoning have occurred both in Tonga and Samoa.

The Colonial Development Corporation managed plantations in Fiji use Paraquat exclusively. Individual Fijian farmers still hand-weed with the cane knife at irregular intervals.

Bananas are grown under widely varying cultural practices in different localities. The number, vigour and species of weeds are influenced by locality, soil, previous cropping history and weed control methods.

No standard weed control programme, therefore, will suit all circumstances and each grower must become familiar with the principles of weed control and plan his own programme.

RICE

This crop, more than any other in the Pacific, shows the ravages of lack of proper weeding. The average yield in Fiji is 16 cwt of padi to the acre on wetland rice (non irrigated). On dryland rice, yield is even lower.

Main weeds in rice in Fiji are Goat Weed, Jungle Rice, Barnyard grass, Para Grass, Sedges, Tar Weed and Sensitive Plant.

Materials such as M.C.P.A. and 2,4-D Ester are used by some of the more progressive farmers. New products such as Stam F-34 are being used by the research stations with excellent results. However, to the average farmer producing 16 cwt of padi to the acre the costs of such materials are out of the question.

Weather conditions often hamper the use of all materials where correct time of application is essential.

The successful attack on the problems of hunger and want which the Western world has done much to overcome, must now be transferred to the under-developed countries.

Western world farmers judged by productivity standards have shown the rest of the world that their output per man or per acre per unit of livestock has put them very near the top of the table. They have done this by learning new ideas, using new machinery and methods, as well as fertilizers with major emphasis on crop production and protection.

As one travels through the S. W. Pacific area as I do, one is appalled at the lack of land use where scrub and bush abound in place of well-cultivated pastures and food crops.

It is to the research worker and extension worker that the mammoth responsibility lies to educate and train farmers of the Pacific.

APPENDIX

COMMON WEEDS OF FIJI AND SUGGESTED METHODS OF CONTROL

CHINESE BURR

(Triumfetta rhomboidea Jacq.)

A fairly common weed in wet zones of Vanua Levu which often is mistaken for Hibiscus Burr. It is resistant to 2,4-D as ester and amine formulations, but can be controlled by slashing or rolling followed with the spraying of the stems and regrowth as soon as it appears with an ester formulation of 2,4,5-Trichlorophenoxy acetic acid at the rate of 3.5 lbs acid equivalent per acre in eighty gallons of fresh water.

FERN

(Nephrolepis exaltata (Linn.) Schott) is common in many parts of Fiji. It is a minor weed of coconut plantations. It has proved resistant to all the selective herbicides and is not seriously damaged by contact chemicals. Slashing with chain slashers or crushing with heavy rollers followed by the sowing of desirable grounds covers has proved an effective control if regularly applied over one or two years.

GUAVA

(Psidium guajava Linn.) is a major weed throughout the coconut plantations. It grows in dense thickets to a height of ten to twenty feet and competes with the coconut palms for the plant food of the soil reducing plantation production in terms of copra and beef. It is a weed of overstocking and ineffective control methods, and, back year after year becomes very difficult to kill even with herbicides.

Although guava is difficult to control, treated correctly it is not impossible. Young seedling plants up to two or three feet in height can be effectively controlled by cutting off three or four inches below the ground surface and pressing the sod back to cover the cut root in the soil. With a sharp spade in stone free soil it is possible for one man to remove up to 200 plants in an eight hour working day. This method is more suitable for the small plantation than for the large estates where labour costs are high. On arable lands guava can be removed with the aid of heavy machinery followed by ploughing and the sowing of a useful ground cover.

Chemical Control: Seedlings and young plants up to two feet in height are effectively controlled by spraying 3.5 lbs acid equivalent per acre of 2,4,5-chlorophenoxy acetic acid as an ester formulation diluted in 80 gallons of water. The large amount of water is necessary to wet the leaves and stems and the coverage is further improved by using pressures of 250 pounds per square inch. The wetting of the stems is an important part of chemical control as the herbicide must be placed over the whole plant to kill all growing points and prevent suckering.

As guaya grows it develops a high degree of resistance to water based foliage sprays and changes have to be made in the method of application.

Cutting the trees off at ground level and applying a mixture of 3.5 lbs a.e. or 2,4,5,-T ester diluted in 30 gallons of diesel fuel oil to the freshly cut stumps and all exposed roots is an effective control.

As an alternative, the above mixture may be applied as a fine spray or with a paint brush to the stems of trees from ground level to a height of three feet, without cutting. As long as all of the bark in the treated area is covered with the mixture the tree will die. 2,4,5-T ester kills slowly and it may take up to 6 months for the guava to die.

HIBISCUS BURR (Urena lobata Linn.) is a wide-spread weed throughout the Fiji Islands. This weed shows a preference for good well-drained soils invading the better lands of the plantations. It is not a difficult weed to control as it is readily susceptible to the following herbicides applied at the rate of 2 lb a.e. per acre diluted in water and applied as a fine spray to the leaves and stems – 2-methyl-4-chlorophenoxyacetic acid, 2,4-dichlorophenoxyacetic acid as an amine salt.

MINT WEED (Hyptis pectinata Linn.) is wide-spread through the high rainfall areas growing in dense thickets to a height of 1

to 12 feet, and it is a most undesirable plant in coconut plantations. However, it is easily controlled by spraying with 2 lbs a.e. of any of the following herbicides:
2-methyl-4-chlorophenoxyacetic acid and the amine or ester formulations of 2,4-dichlorophenoxy acetic acid.

LANTANA (Lantana camara Linn.) is a major problem on many coconut plantations which has been aided in its spread by overstocking. The dense thickets increase the cost of copra production and it possesses certain toxic properties which cause poisoning and death when grazed by livestock.

Uprooting is an effective control as long as the complete root system is removed from the soil, as broken roots are capable of sending up new top growth.

In sites where it is possible to operate farm machinery, the growing plants can be grubbed out mechanically and the regrowth sprayed. This is an effective method of control. Lantana is resistant to the ester formulations of 2,4-D and 2,4,5-T but readily susceptible to the amine formulations of 2,4-dichlorophenoxyacetic acid applied at the rate of 4 to 5 pounds acid equivalent per acre diluted in water. The spray mixture should wet both the leaves and canes. This is an important part of the control as this is another weed which has growing points spread the full length of the canes. The herbicides can be applied without pretreatment but the degree of control is greatly improved if the weed is first crashed or slashed and the spray applied when there is plenty of fresh new leaf.

Of the newer herbicides, the following commercial mixtures have given effective control:

1. 4,amino – 3,6,5-trichloropicolinic acid 0.5 lbs a.e. 2,4-dichlorophenoxyacetic acid as an amine. 2 lbs a.e. per acre.
2. 4,amino – 3,6,5-trichloropicolinic acid 0.75 lbs a.e. 2,4,5-trichlorophenoxyacetic acid as an amine 2.0 lbs a.e. per acre.

These herbicides were diluted in water and applied with and without pretreatment at the rate of 80 gallons of spray mixture per acre.

Both treatments gave a complete kill of lantana when the spraying was carried out with Rega knapsack sprayers at a pressure of approximately 25 lbs per square inch.

Except to allow better coverage and free movement through the thickets, there appears to be no advantage in pre-treating the lantana with these herbicides.

TOBACCO WEED (Elephantopus mollis H. B.K.) is a comparatively new weed to the coconut industry which can be controlled by spraying with 2 lbs acid equivalent of 2,4-dichlorophenoxyacetic acid as an ester or amine formulation.

NAVUA SEDGE (Cyperus aromaticus (Ridley) Mattf. & Kukenth) A vigorous and aggressive weed of the coastal districts and river valleys of many islands of Fiji. In agricultural and plantation lands it competes with the crop plants for the available mineral nutrients, water and sunlight, reducing production in terms of crop yields, and it is a potential breeding place for rats, insect pests and plant diseases.

Control: Strict control measures with regard to stock, seed and even planting material from infected areas should be enforced. Several chemicals will effectively control *Navua sedge* if correctly applied. The most successful is the ester formulation of 4 chlorophenoxyacetic acid plus sodium chlorate. These two herbicides are mixed together at the rate of 4 lb a.e. of 4 C.P.A. plus 2 lbs sodium chlorate 100% diluted in 80 gallons of water. As the *sedge* matures and sets seed this mixture has to be increased using up to 8 lbs a.e. of 4-C.P.A. plus 2 lbs sodium chlorate diluted in 80 gallons of water per acre.

BLUE RAT'S TAIL
(Stachytarpheta urticaefolia Vahl.)
KAUMOCE
(Cassia tora Linn.)
MILE–A–MINUTE
(Mikania micrantha H.B.K.)
NUT GRASS
(Cyperus rotundus Linn.)
WILD PASSIONFRUIT OR STINKING PASSION FLOWER
(Passiflora foetida Linn.)
PRICKLY CUCUMBER
(Coccinea cordifolia (Linn.) Cogn.)
JOHNSON'S GRASS
(Sorghum halepense (Linn.) Pers.)
SENSITIVE GRASS
(Mimosa pudica Linn.)
GOAT WEED
(Ageratum conyzoides Linn.;
Ageratum houstonianum Mill.)
BARNYARD GRASS
(Echinochloa crus-galli (Linn.) Beauv., and E. *colonum* (Linn.) Link).
PARA GRASS
(Brachiaria mutica (Forsk.) Stapf).
TAR WEED
(Cuphea carthagenesis (Jacq.) Macbr.)

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Heavy infestation in a coconut grove in Hawaii. Weeds create serious management problems in copra plantations throughout the Asian-Pacific region.

WEEDS AND WEED CONTROL BY CHEMICALS IN TAIWAN

Wei-huai Horng[1]

Weed control by chemicals was totally unknown to Taiwan farmers some 15 years ago. Hand weeding or tillage by animal-drawn cultivators were widely practiced by small-farm tillers because labor could be readily provided by the farmers themselves. Up to today hand weeding is still the popular means for controlling weeds in individual farms. Only in such large farms like sugar cane plantations, tillage by mechanical cultivators was used. But where and when farm labor shortage became a problem, big farms such as the Taiwan Sugar Corporation, or the farms owned by the Taiwan Pineapple Corporation, have attempted to use herbicides in place of the traditional method of hand weeding, not only for the reason of reducing the cost of labor but also for the fact that weeding by hired laborers was usually far from being adequate to prevent regrowth of weeds that took away soil nutrients and resulted in a decrease of crop yield. Recently, the multiple cropping methods promoted by the Government and adopted by the farmers have kept the latter busy in farming almost the entire year, consequently more and more farmers are using herbicides. As a result, there is an increasing use of chemicals for weed control.

COMMON WEEDS OF FARMS IN TAIWAN

More than 170 species of weeds belonging to more than 46 genera have been found in Taiwan farmland planted to rice and major dryland food crops. A comprehensive study on the botanical classification and description of the weeds based on a survey of the regional distribution and investigation on the occurrence of individual species was completed in 1963 under a joint project supported by the Joint Commission on Rural Reconstruction (JCRR), in cooperation with the National Taiwan University, various district agricultural improvement stations and the Seed Testing Laboratory of the Provincial Department of Agriculture and Forestry (PDAF). It covered a total of 595 sampling sites in the rice fields, each with an area of 5 feet by 40 feet in Taipei, Hsinchu, Taichung and Kaohsiung, and 383 sampling sites in the dryland crop fields, each with an area of 8 feet by 40 feet in Taichung and Tainan. For those rice fields in the Taichung area where one winter crop was usually grown after two crops of rice, weed samples were separately collected from a total of 171 sampling sites in those fields planted to different winter crops such as wheat, sweet potato, flax, tobacco, potato, soybean, rape, etc., depending on the rotational practices in the particular places. Weeds sampled from dryland farms were based on different kinds of crops planted on them. The results of the survey on weeds of farms are summarized as follows:

A. Rice crop

Ninety-two species belonging to 31 genera, and 73 species belonging to 25 genera were found in the first and second rice crop respectively in the Taipei, Hsinchu, Taichung and Kaohsiung areas. Table 1 lists the most common weeds listed in the order of decreasing frequency of occurrence.

Table 1. Common Weeds In Rice Field (in order of decreasing importance).

Species	Family	Annual/ Perennial	Locality
1st rice crop:			
Echinochloa crus-galli Beauv.	Gramineae	Annual	Tpe, Hch, Tch, Khg[1]
Monochoria vaginalis Presl.	Pontederiaceae	Annual	Tpe, Hch, Tch, Khg
Cyperus difformis Linn.	Cyperaceae	Annual	Hch, Tch, Khg
Lindernia pyxidaria All.	Scrophulariaceae	Annual	Hch, Tch, Khg
Sagittaria sagittifolia Lour. (= *Sagitaria trifolia* Linn.)	Alismataceae	Perennial	Tpe, Hch, Khg
Fimbristylis miliacea (Linn) Vahl.	Cyperaceae	Annual	Tpe, Hch, Tch
Eleocharis acicularis R. & S.	Cyperaceae	Annual	Tpe, Hch, Tch
Eclipta prostrata (L.) Linn. (= *Eclipta alba* Hassk.)	Compositae	Annual	Tch, Khg
Rotala indica (Willd.) Koehne	Lythraceae	Annual	Hch, Khg
Lindernia cordifolia Merr.	Scrophulariaceae	Annual	Tch
Kyllinga brevifolia Rottb.	Cyperaceae	Perennial	Tpe
Rotala rotundifolia Koehne	Lythraceae	Perennial	Tpe
Scirpus wallichii Nees.	Cyperaceae	Perennial	Khg
Dopatorium junceum Hamilt.	Scrophulariaceae	Annual	Tch
Marsilea quadrifolia Linn.	Marsileaceae	Perennial	Tpe, Khg
2nd rice crop:			
Monochoria vaginalis Presl.	See above	See above	Tpe, Hch, Tch, Khg
Echinochloa crus-galli Beauv.	"	"	Tpe, Hch, Tch, Khg
Fimbristylis miliacea (Linn) Vahl.	"	"	Tpe, Hch, Tch, Khg
Rotala indica (Willd.) Koehne	"	"	Tpe, Hch, Khg
Marsilea quadrifolia Linn.	"	"	Tpe, Hch, Khg
Sagittaria sagittifolia Lour.	"	"	Tpe, Hch, Khg
Cyperus difformis Linn.	"	"	Tch, Khg
Eclipta prostrata (L.) Linn.	"	"	Tch, Khg
Lindernia pyxidaria All.	"	"	Tch, Khg
Lindernia cordifolia Merr.	"	"	Tpe, Tch
Ludwigia prostrata Roxb.	Oenotheraceae	Annual	Tpe, Hch
Dopatorium junceum Hamilt.	See above	See above	Tch
Juncus prismatocarpus R. Br.	Juncaceae	Annual	Tpe
Alternanthera sessilis R. Br.	Amaranthaceae	Annual	Tch
Cyperus rotundus Linn.	Cyperaceae	Perennial	Khg

[1] Tpe: Taipei; Hch: Hsinchu; Tch: Taichunt; Khg: Kaohsiung.

[1]Specialist, Plant Industry Division, Joint Commission on Rural Reconstruction, Taiwan, Republic of China.

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B. Winter Crops in Taichung Rice Field

A total of 49 species belonging to 16 genera were found in the rice fields planted to various winter crops after two crops of rice in the Taichung area. Table 2 lists the most common weeds in the order of decreasing frequency of occurrence.

C. Dryland Crops in Tainan Area

A total of 63 species belong to 26 genera was found in the dryland crop fields planted to peanut, sweet potato, soybean, jute, dryland rice, rape, etc. in the Tainan area. Table 3 lists most common weeds listed in the order of decreasing frequency of occurrence.

EXPERIMENTS ON WEED CONTROL BY CHEMICALS

In Taiwan, chemical weed control was first started on sugarcane plantations in 1951 and, a few years later, on pineapple fields. Experiments on the use of herbicides in rice fields in 1950's were occasionally conducted at various district agricultural improvement stations without satisfactory results mainly due to the lack of suitable chemicals at that time. It was not until 1963 when the need of chemical weed control for the rice field was keenly felt in those places where the village labor was of comparatively high cost and sometimes insufficient during the busy months the weed control by newer herbicides had proved successful and rewarding. Trial use of herbicides on dryland food crops began in 1963 but was only practised to a limited extent.

A. Rice crop

In 1964-65, a number of herbicides were widely tested for weed control in rice fields at various agricultural experiment stations and district agricultural improvement stations under JCRR support. Results obtained from the experiments in Taipei, Taichung, Kaohsiung, Hualien and Taitung may be summarized as follows:

1. TOK(2,4-dichlorophenyl-4-nitrophenyl ether) applied at a rate of 30 kg of 5% granules per hectare 5 to 7 days after transplanting of rice plants for 1st crop 3 to 5 days after transplanting for 2nd crop with irrigation water maintained at a depth of 3 centimeters for 3 to 5 days after application of the chemical was effective in controlling *Echinochloa crus-galli*, *Monochoria vaginalis*, *Eleocharis acicularis* for 30 to 40 days, and partially effective for the control of

Table 2. Common weeds in winter crop field after two crops of rice (in order of decreasing importance).

Species	Family	Annual/Perennial
Wheat:		
Chenopodium ficifolium Sm.	Chenopodiaceae	Annual
Stellaria aquatica (Linn.) Scop.	Caryophyllaceae	Perennial
Polygonum hydropiper Linn. (= *Polygonum blume* Mersn.)	Polygonaceae	Annual
Gnaphalium indicum Linn.	Compositae	Annual
Mazus japonicus O. Kuntze	Scrophulariaceae	Annual
Tobacco:		
Chenopodium ficifolium Sm.	See above	See above
Stellaria aquatica (Linn.) Scop.	"	"
Amaranthus spinosus Linn.	Amaranthaceae	Annual
Gnaphalium indicum Linn.	See above	See above
Polygonum hydropiper Linn.	"	"
Paspalum conjugatum Berg.	Gramineae	Perennial
Mazus japonicus O. Kuntze	See above	See above
Sweet potato:		
Chenopodium ficifolium Sm.	See above	See above
Stellaria aquatica (Linn.) Scop.	"	"
Alopecurus aequalis Sobol. var. *amurensis* (Komar.) Ohwi. (= *Alopecurus geniculatus* Linn.)	Gramineae	Annual
Gnaphalium indicum Linn.	See above	See above
Rape:		
Chenopodium ficifolium Sm.	Chenopodiaceae	Annual
Stellaria aquatica (Linn.) Scop.	Caryophyllaceae	Perennial
Polygonum hydropiper Linn.	Polygonaceae	Annual
Alopecurus aequalis Sobol.	Gramineae	Annual
Mazus japonicus O. Kuntze	Scrophulariaceae	Annual
Gnaphalium indicum Linn.	Compositae	Annual
Flax:		
Mazus japonicus O. Kuntze	See above	See above
Stellaria aquatica (Linn.) Scop.	"	"
Polygonum hydropiper Linn.	"	"
Chenopodium ficifolium Sm.	"	"
Eclipta prostrata (L.) Linn.	Compositae	Annual
Gnaphalium indicum Linn.	See above	See above
Potato:		
Stellaria aquatica (Linn.) Scop.	See above	See above
Chenopodium ficifolium Sm.	"	"
Alopecurus aequalis Sobol.	"	"
Polygonum hydropiper Linn.	"	"

Cyperus difformis, but ineffective against *Marsilea quadrifolia*. No phytotoxicity was noticed under the treatment conditions. This herbicide is suitable for use in many types of paddy soils in Taiwan. The yield of rice in the treated field was 10 to 35% higher than that of the control, or 10% less to about the same in comparison with that by hand weeding (usually 3 times for 1st crop and 2 times for 2nd crop). For those established weeds and *Marsilea quadrifolia* which could not be controlled by the chemical, it was recommended that weeding should be done at the time of land preparation.

2. Casoron (2,6-Dichlorobenzonitrile) applied at a rate of 2 kg of 50% WP per hectare 5 to 7 days after transplanting of rice plants with irrigation water kept at a depth of 3 centimeters for 2 to 3 days after the herbicidal application gave good control of *Echinochloa crus-galli*, *Monochoia vaginalis*, *Eleocharis acicularis*, *Cyperus difformis* and many other weeds except *Marsilea quadrifolia*. However, some phytotoxicity over the young rice plants was observed in case the soil was too sandy to hold enough irrigation water in the field. The yield of rice in the treated field was 17 to 40% more than that of the control or nearly the same as that by usual hand weeding.
3. Glenbar (Thiomethyl ester of 2,3,5,6-tetrachloro-4-carbomethoxybenzoic acid) applied at a rate of 15 liters of 12% EC per hectare 3 to 5 days after transplanting of rice with irrigation water kept at 3 to 5 centimeters deep for 3 to 5 days after the herbicidal application was effective against *Echinochloa crus-galli*, *Eleocharis acicularis* up to 40 days, and fairly effective against *Cyperus difformis*. Like TOK and Casoron, this chemical was ineffective against *Marsilea quadrifolia*. The yield of rice in the treated field was 5 to 15% less than that by hand weeding. Phytotoxicity was never noticed at the above-mentioned rate when irrigation water in the treated field was not adequately maintained.
4. Ordram (S-ethyl hexahydro-1 H-azepine-1-carbothioate) applied at a rate of 6.5 liters of 71.3% EC per hectare 14 days after transplanting of rice plants with irrigation water kept at a

Table 3. Common weeds in dryland crop field (in order of decreasing importance).

Species	Family	Annual/ Perennial
Peanut, spring-planting after rice:		
Echinochloa colona (L.) Link.	Gramineae	Annual
Echinochloa crus-galli Beauv.	Gramineae	Annual
Digitaria sericea (Honda) Honda	Gramineae	Annual
Eleusine indica Gaertn.	Gramineae	Annual
Physalis angulata Linn.	Solanaceae	Annual
Amaranthus viridis Linn.	Amaranthaceae	Annual
Cyperus rotundus Linn.	Cyperaceae	Perennial
Peanut, spring-planting after miscellaneous food crops:		
Digitaria sericea (Honda) Honda	See above	See above
Echinochloa colona (L.) Link.	"	"
Eleusine indica Gaertn.	"	"
Cyperus rotundus Linn.	"	"
Amaranthus viridis Linn.	"	"
Physalis angulata Linn.	"	"
Euphorbia hirta Linn.	Euphorbiaceae	Annual
Echinochloa crus-galli Beauv.	See above	See above
Peanut, fall-planting:		
Echinochloa colona (L.) Link.	See above	See above
Digitaria sericea (Honda) Honda	"	"
Eleusine indica Gaertn.	"	"
Echinochloa crus-galli Beauv.	"	"
Amaranthus viridis Linn.	"	"
Cyperus rotundus Linn.	"	"
Sweet potato, after rice:		
Cyperus rotundus Linn.	See above	See above
Chenopidium ficifolium Sm.	Chenopodiaceae	Annual
Physalis angulata Linn.	See above	See above
Eleusine indica Gaertn.	"	"
Echinochloa crus-galli Beauv.	"	"
Digitaria sericea (Honda) Honda	"	"
Amaranthus viridis Linn.	"	"
Echinochloa colona (L.) Link.	"	"
Portulaca oleracea Linn.	Portulacaceae	Annual
Sweet potato, after dryland crop:		
Eleusine indica Gaertn.	Gramineae	Annual
Digitaria sericea (Honda) Honda	Gramineae	Annual
Amaranthus viridis Linn.	Amaranthaceae	Annual
Echinochloa Colona (L.) Link.	Gramineae	Annual
Echinochloa crus-galli Beauv.	Gramineae	Annual
Portulaca oleracea Linn.	Portulacaceae	Annual
Soybean:		
Digitaria sericea (Honda) Honda	See above	See above
Physalis angulata Linn.	Solanaceae	Annual
Eleusine indica Gaertn.	See above	See above
Echinochloa colona (L.) Link.	"	"
Chenopodium ficifolium Sm.	Chenopodiaceae	Annual
Echinochloa crus-galli Beauv.	See above	See above

Continued on page 19

Table 3 (continued from page 18)

Species	Family	Annual/ Perennial
Dryland rice:		
Echinochloa colona (L.) Link.	See above	See above
Pycreus polystachus Beauv.	Cyperaceae	Annual
Portulaca oleracea Linn.	See above	See above
Eleusine indica Gaertn.	"	"
Echinochloa crus-galli Beauv.	"	"
Digitaria sericea (Honda) Honda	"	"
Amaranthus viridis Linn.	"	"
Cyperus rotundus Linn.	Cyperaceae	Perennial
Jute:		
Echinochloa colona (L.) Link	See above	See above
Eleusine indica Gaertn.	"	"
Digitaria sericea (Honda) Honda	"	"
Amaranthus viridis Linn.	"	"
Cyperus rotundus Linn.	"	"
Pycreus polystachus Beauv.	"	"
Rape:		
Echinochloa colona (L.) Link.	See above	See above
Eleusine indica Gaertn.	"	"
Digitaria sericea (Honda) Honda	"	"
Portulaca oleracea Linn.	"	"
Euphorbia hirta Linn.	Euphorbiaceae	Annual
Digitaria violascens Link.	Gramineae	Annual

depth of 3 to 5 centimeters after application of the herbicide was very effective against *Echinochloa crus-galli* and gave a good control of *Portulaca oleracea*, *Marsilea quadrifolia*, *Monochoria vaginalis* without noticeable adverse effects on rice growth, but was partially effective against *Eleocharis acicularis*. The yield of rice in the treated field was 5 to 10% more than that by hand weeding. If the herbicide was applied at a rate higher than 6.5 liters per hectare 7 days after transplanting, young rice plants showed stunting at the early stage, but recovered after 2 to 3 weeks.

5. PCP or Pancom (PCP sodium salt 13.4% and 2-methyl-4-chlorophenoxyacetic acid allyl ester 1.2%) applied at a rate of 30 kg of PCP sodium salt 25% granules of Pancom granules per hectare 7 days after transplanting of rice plants for 1st crop or 4 days after transplanting for 2nd crop with irrigation water kept at a depth of 3 centimeters for 10 days after the application of herbicide gave a fairly good control against *Echinochloa crus-galli*, *Eleocharis acicularis*, *Cyperus difformis*, *Monochoria vaginalis*. The rice yield in treated field was 20% less to about the same as compared with that by hand weeding. Their use is limited in those places where the problem of fish poison is involved.

6. For a good control of barnyard grass in the rice field, emphasis has been placed on the control of the grass in the nursery bed, because the grass is usually carried over with young rice plants during the process of transplanting. It was found that Glenbar applied at a rate of 15 liters of 12% EC per hectare right after rice seeds were sowed and the soils were covered with a layer of wood ashes produced a satisfactory control. Stam (3,4-dichloropropionanilide) applied in two equal portions of 2 liters of 35% EC per hectare when the first two leaves of rice plant appeared and then at the time 3 to 5 days after the first application of herbicide was also effective. However, young rice plants of the 2nd crop might be injured at a temperature higher than 26 degrees Centigrade. Therefore, Stam was recommended for use only in the 1st rice crop.

B. Sugarcane

Sodium salt of 2,4-D was the first herbicide tested and recommended for general use in sugarcane fields. One pre-emergence application at a rate of 3 kg per hectare followed by 2 to 3 post-emergence applications of 2 kg/ha. each at an interval of one month during the first 5 months of cane growth and before cane leaves were closed in was usually satisfactory for control of broadleaves, especially nut grass. Diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea) or atrazine (2-chloro-4-isopropylamino-6-ethylamino-s-triazine) was found to be effective in controlling all broadleaves and most graminaceous weeds for 2 to 3 months with least danger of phytotoxicity to germinating cane seedlings when used as pre-emergence application at rate of 3 kg of diuron 80% WP per hectare or 5 kg of atrazine 50% WP per hectare. These two herbicides were less effective in controlling *Cyperus rotundus*, *Panicum repens* and *Cynodon dactylon* at the afore-mentioned rates and usually so in preventing deep-seated roots of nut sedges and old rhizomes of perennials from sending out new shoots later. To control a variety of weeds and to save cost of the chemicals used, either diuron at 2 kg/ha. or atrazine at 3 kg/ha. has been used in combination with 2,4-D sodium salt at 2 kg/ha. in recent years. Sugarcane yields obtained from chemical weed control on the Taiwan Sugar Corporation-owned farms were about 10% more than that by hand weeding. There might be erratic results in the yield of cane from chemical weed control due to too much or too little rainfall after application of the herbicide, soil types or other factors influencing the effectiveness of herbicide.

C. Pineapple

Diuron and atrazine were also found effective in controlling weeds on pineapple plantations by the band treatment at rates of 1.5 kg/ha. and 3 kg/ha., respectively. For orchards with newly planted pineapple, the doses of both chemicals may be doubled. A 3-year spray program using these chemicals for weed control in newly planted orchards has been worked out.

D. Dryland crops

TOK and PCP sodium salt applied at rates of 6 to 8 liters of 25% EC per hectare and 12 to 15 kg of 86% powder per hectare respectively after sowing and before germination of seeds were found effective in controlling *Portulaca oleracea*, *Eleusine indica* and *Echinochloa crus-galli* in peanut, soybean and sorghum fields, but partially effective against *Digitaria violascens*. Because PCP was effective for about 3 weeks, one additional application of the same rate at about 25 days after the first application was needed for a better control of *Portulaca oleracea* and *Eleusine indica*. No phytotoxicity was noticed under the treatment conditions for both chemicals.

The afore-mentioned herbicides have been recommended by the Government for general use after they were proved satisfactory in the control of weeds. New herbicides currently under field trials include Trifluralin (trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine), MO (2,4,6-trichlorophenyl-4'-nitrophenyl ether), OCS-21799 (2,(4-chloro-O-tolyloxy) N-methoxyacetamide, an experimental herbicide of the Velsicol Chemical Corp., SWEP (methyl-(3,4-dichlorophenyl) carbamate), Eptam (ethyl N,N-di-n-propyl thiolcarbamate), etc., among which MO, trifluralin and OCS-21799 showed good control of barnyard grass in the rice field.

SOME GENERAL PRINCIPLES OF WEED CONTROL

Arnold P. Appleby[1]

The task of discussing general principles of weed control is a difficult and complex one and certainly cannot be accomplished in a thirty-minute presentation. Therefore, I propose to discuss weed control in general terms and then cite some general principles as examples, recognizing that a great number of ideas and concepts are being omitted.

There are a number of definitions for a weed, but perhaps the most widely used one is that a weed is "a plant out of place" or "a plant growing where it is not wanted". For the more poetically inclined, a definition has been advanced by Emerson that a weed is "a plant whose virtues have not yet been discovered". Weed control is the process of reducing the undesirable effect of weeds to a minimum. It is accomplished by adjusting the environment to make it as unsuitable for weed growth as possible. This is an important point and one that weed control workers in general should recognize more fully. All too often, weed control is carried out by one single method rather than recognizing that our main objective is to manipulate the environment of the weeds. This can be accomplished physically (tillage, fire, flooding, smothering), culturally (crop rotation, smother crops), biologically, or chemically. Generally a combination of these methods is more desirable and more effective than any one method used alone.

An example of what may be considered a principle involved in physical weed control would be that young leaves use food from the roots for a considerable time after emergence and therefore help deplete the root reserves. Therefore, cultivation should be delayed until the carbohydrate flow from the roots ceases and the leaves begin to manufacture enough food to start replenishing the root reserves. Therefore, with most perennial weeds, tillage 10 to 14 days after emergence is more effective in carbohydrate starvation than tillage immediately after emergence.

An important concept in biological weed control is that the weed population and the insect population undergo cycles. Often the weed population will decrease rapidly until many of the insect predators have starved; then often the weed population will increase rapidly for a short period of time until the insect population has built back up. These cycles generally will continue until the weed population has more or less stabilized at a low level.

Herbicide selectivity is the result of a chemical reaching and disrupting a vital function in one plant and not in another. Selectivity may depend on many mechanical, physical, chemical, or metabolic aspects. Some examples of these aspects are as follows:

1. Directed placement of the spray. The weed plants are contacted by the spray but the crop plants are not.
2. Differential wetting of the leaf surface. Mustard can be controlled selectively in peas with contact herbicides because the pea leaves are waxy and the spray solution is not retained on the leaves. The mustard leaves are much less waxy, allowing the herbicide to penetrate the leaf surface and kill the plant.

[1] Associate Professor, Farm Crops Department, Oregon State University.

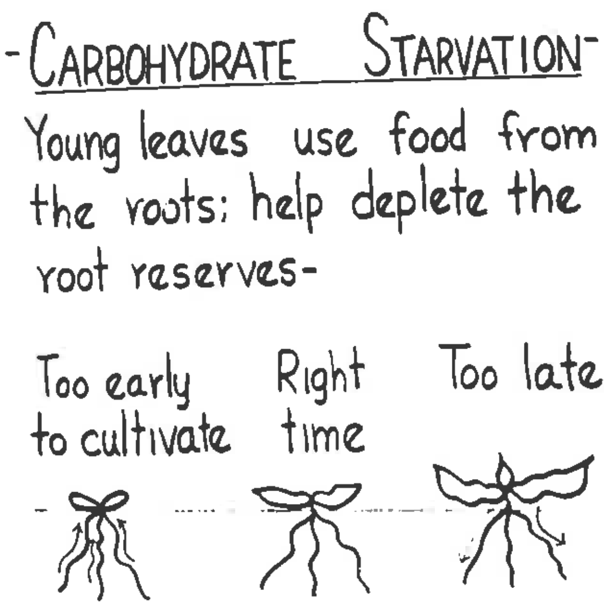

Fig. 1. Cultivation for depletion of root reserves should be delayed until the carbohydrate flow from the roots ceases and the leaves begin to manufacture food.

3. Depth of rooting. Many annual weeds can be controlled in established alfalfa with simazine because the alfalfa roots extend below the area of high simazine concentration. The annual weeds are rooted directly in the simazine-treated soil and are destroyed.
4. Differential decomposition of herbicides. Many weeds can be controlled selectively in corn with atrazine because the corn detoxifies the atrazine very rapidly whereas the weeds are unable to break down atrazine quickly enough to prevent their death.
5. Activation of herbicide. Pigweed can be controlled in seedling alfalfa with 2,4-DB because the pigweed breaks down the non-toxic 2,4-DB to toxic 2,4-D. Alfalfa does not possess sufficient enzymes to make this conversion; therefore, little or no 2,4-D is formed and the alfalfa plant remains healthy.

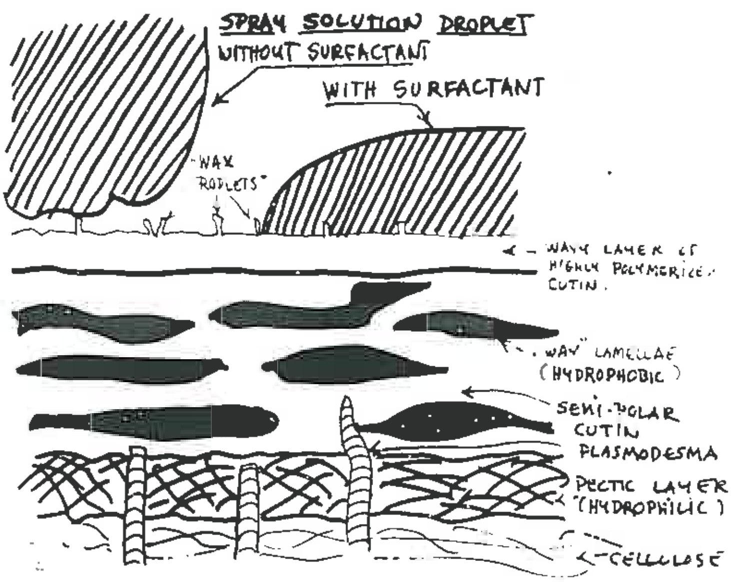

Fig. 2. Schematic View of plant cuticle and epidermal cell walls.

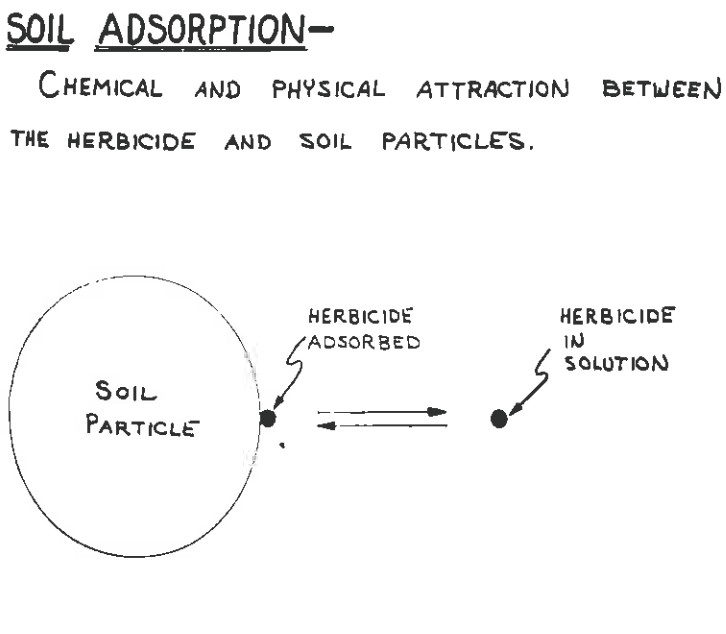

Fig. 3. Herbicide adsorption on soil is an important process which greatly influences herbicidal activity.

Selectivity does not only exist between crops and weeds but also between various species of weeds themselves. This fact can cause some very important ecological shifts when using herbicides in a mixed population of weeds. Often certain species of weeds are not controlled by a particular herbicide and may become dominant when competition from other weeds is removed. This process may give rise to monocultures of weeds which may be more troublesome than the original population. This can be a particularly serious problem in tropical areas where weed growth and reproduction is rapid. To counteract undesirable shifts in the weed population, crop rotations with new cultural practices can sometimes be used to prevent any particular species from becoming dominant. As more effective and selective herbicides become available, herbicide rotations become more feasible, that is, using one herbicide one season and a second herbicide the following season. Combinations of two or more herbicides can also help prevent uncontrolled weeds from becoming dominant. An undesirable shift in plant population is one of the hazards of using herbicides without proper regard for ecological principles.

Many other aspects of herbicide use will be discussed by other speakers at this conference. As an example of factors and information that must be considered in using herbicides, let us consider the process of absorption of a herbicide into a plant leaf. Although this process sounds rather simple, it is really a rather complex procedure. We must remember that leaves are not especially effective as absorbing organs, as are roots. A number of very effective soil-active herbicides are ineffective when applied to the foliage. Care must be exercised when using foliage-applied herbicides to meet all of the many requirements in guiding the herbicide molecules through the plant cuticle. Environmental conditions such as temperature and humidity before and after spraying, herbicide formulation, volume of carrier, surfactants, etc., can all have a considerable influence on the performance of foliage-applied materials.

Herbicides can enter the plant leaf either through the stomates or through the cuticle. We will consider only cuticular entry in this discussion. We will turn our attention now to the nature of this cuticle and the pathways a herbicide can follow in its journey from the leaf surface to the translocating tissue within the leaf. The cuticle and outer wall of the epidermal cells consist of four materials: waxes, pectin, cellulose, and cutin. The properties of these materials directly influence the manner in which a herbicide can penetrate the leaf. Waxes are oil-soluble (lipophilic) and are readily penetrated by many organic solvents, but generally resist water. Pectins and cellulose are hydrophilic; i.e., they can absorb water or other polar materials. Cutin is a sort of hybrid material that is partly oil-soluble and partly water-soluble. It can act as a binding agent between the lipophilic wax and the hydrophilic pectins and cellulose. It would seem at first glance that a water-soluble herbicide would have a very difficult time getting into the plant leaf because of the wax barrier. Fortunately, however, this waxy layer generally has many cracks, insect punctures, mechanical injuries, etc. Also, some areas of the waxy layer are impregnated with cutin which has the ability to absorb a certain amount of water, offering a pathway for the water-soluble herbicide to travel in passing through the waxy barrier. Pectins and cellulose can likewise absorb water, causing them to swell and allowing a much easier penetration of water-soluble herbicides. This partially explains why greater activity is often observed with water-soluble herbicides under high humidity conditions. Oil-soluble herbicides can move through the cuticle primarily through the waxes and oil-soluble part of the cutin. Water-soluble herbicides, then, transverse an "aqueous" route and oil-soluble herbicides follow a "lipoidal" route.

Many important principles involving the use of herbicides are concerned with interactions between the herbicide and soil. Soil adsorption is the chemical and physical

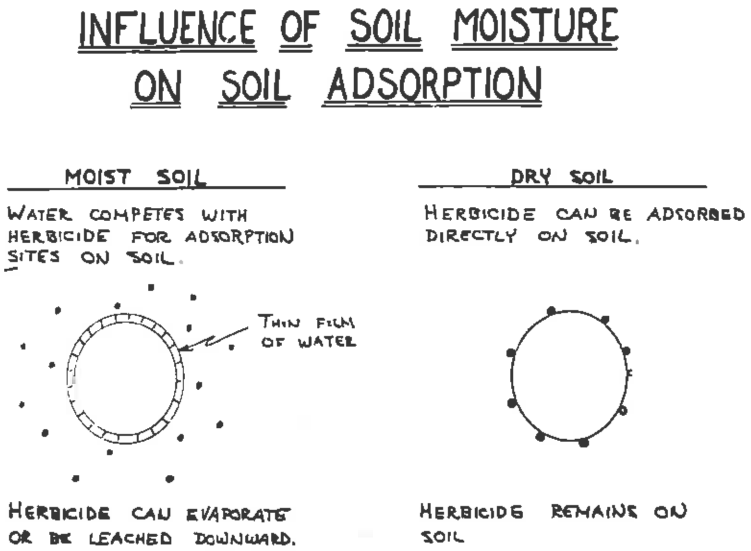

Fig. 4. When herbicides are applied to moist soil, adsorption is often less rapid because of competition with water for adsorption sites than when application is made to dry soil.

attraction between the herbicide and soil particles. This is an extremely important process in the soil and one which we must pay a considerable amount of attention to in using herbicides intelligently. Several factors influence adsorption to a certain extent. Organic matter, soil texture, and type of clay are all important. We now think that soil moisture may have a considerable influence on soil adsorption. When herbicides are applied to moist soil, water competes with the herbicide for adsorption sites on the soil particles. The herbicide is not adsorbed as tightly and can evaporate or be leached downward. When the herbicide is applied to dry soil, adsorption seems to be more rapid and complete, thereby preventing loss and resulting in greater weed control. This seems particularly important with uracil herbicides. Of course, if adsorption is so complete that weeds are unable to absorb the herbicide, poorer weed control may result.

This has been a rapid and incomplete discussion of a few concepts and principles of weed control. There are many other areas that could have been discussed if time permitted. A great deal remains to be learned about the principles of weed control. As we learn more about these principles and put them into use, our success in controlling undesirable plants will increase.

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3 NEW HERBICIDES FOR TROPICS AND SUBTROPICS

A PROMISING NEW HERBICIDE FOR TROPICAL AGRICULTURE

A. J. Watson and A. W. Swezey[1]

A new herbicide, 2,3,5-trichloro-4-pyridinol, known under the trademark DAXTRON, has shown considerable promise for certain uses related to tropical agriculture. This is a progress report and briefly summarizes results obtained to date using a potassium salt formulation. While a considerable amount of research has been done on each of the crops discussed, more work is needed in the specific geographical areas of intended use. To date DAXTRON herbicide has not been registered in any country for commercial use, but work is underway to obtain the necessary data for the more promising uses.

GENERAL BIOLOGICAL ACTIVITY

Daxtron herbicide is a highly active systemic weed killer that is absorbed and translocated by both roots and foliage. Also, contact activity is usually apparent following foliar applications. Chlorosis occurs on the new growth of many plant species following either soil or foliar applications and is reversible at sub-lethal dosages. This observation suggests that a possible mechanism of action is interference with chlorophyll synthesis and also indicates that at least some plants may have a means of detoxifying the compound.

DAXTRON herbicide has a broad spectrum of activity. It is especially effective on most grass species and controls many broadleaved weeds as well. Used alone or in combination with a more active broadleaved weed killer such as 4-amino 3,5,6-trichloropicolinic acid (TORDON herbicide), it is useful for complete vegetation control in noncrop areas (3).

This herbicide is also useful selectively in certain crops such as sugarcane and peanuts. These crops will tolerate rates applied pre-emergence that are effective for residual control of most annual weed species. Certain other crops such as bananas, coconut, African oil palm, rubber and possibly coffee and pineapple are tolerant to directed sprays of the herbicide. With established plantings of these crops, rates of 0.4 to 2 lb/A may be used safely as directed sprays. These dosages normally control the weeds that are present and provide residual pre-emergence control of annuals for a period of two or three months.

Dosage required for effective weed control varies considerably with species and method of use. For example, rates of 0.4 to 1.5 lb/A are effective when applied pre-emergence or early postemergence on most annual species while established perennial grasses may require 2.0 lb/A or more. Certain established perennial grasses such as bermudagrass *(Cynodon dactylon)* and johnsongrass *(Sorghum halepense L.)* are more resistant to the compound and require rates of 10 lb/A or more in single applications for good control.

Weed response to Daxtron herbicide also varies considerably with stage and rate of growth of the plants when sprayed. Best control is obtained when weeds are young and actively growing. Conversely, poor results can be expected from applications made to mature, drouth stressed weeds. It appears this herbicide is not readily absorbed through leaves or translocated well under these droughty conditions.

BEHAVIOR IN SOIL

While DAXTRON herbicide is moderately persistent in soil, it is subject to both leaching and microbial decomposition. Since it is water soluble, rate of leaching is dependent largely upon amount and distribution of rainfall and soil texture. Laboratory leaching studies have demonstrated that it is not strongly sorbed by clay or organic matter.

Microbial breakdown proceeds relatively slowly under most field conditions. Rate of decomposition is closely related to the microbial activity level in the soil.

Field studies in Mississippi and Colombia indicate that in areas of moderate rainfall there should be little or no residual carry over after 12 months in most tropical soils from applications of 2 lb/A or less. A considerable faster rate of loss would be expected in tropical areas having higher rainfall.

CROP USES

This herbicide has shown considerable promise for use in certain crops important to tropical agriculture. A brief resume of the field studies conducted to date follows:

Sugarcane

Field trials have been conducted with sugarcane in Louisiana, Florida, Jamaica, Puerto Rico, Trinidad, Colombia and Hawaii. Studies have involved pre-emergence applications to plant cane, pre-emergence to ratoon cane after harvest and a limited number of post-emergence directed trials.

Typical pre-emergence weed control data from tests conducted on loam to clay loam soils in the Cauca Valley of Colombia are presented in Table 1. Excellent residual control of annual grasses represented by the genera *Eleusine, Echinochloa, Setaria, Panicum,* and *Digitaria* was obtained for periods of 90 to 120 days with rates of 1.0 lb or more per acre. Residual control of broadleaved weeds was considered commercially acceptable in some but not in all tests. The broadleaved weed genera *Euphorbia* and *Commelina* often survived treatment with DAXTRON herbicide. Further research is needed to determine the best program, including combinations of herbicides, to handle the tolerant broadleaved species. No injury or growth reduction of the cane was apparent in any of these experiments on loam to loam clay soils typical of most cane growing areas of Colombia.

Pre-emergence trials on plant cane were conducted also on very light sandy loam soil near Cali, Colombia. As the data in Table 2 indicate, excellent control of annual grasses (mostly *Eleusine indica*) was obtained for as long as 100 days with 1.0 lb/A or more. Chlorosis of the crop was observed in these experiments on sandy loam soil. Little or no chlorosis developed at rates of 1.0 lb/A or less, however, with 2.0 lb/A a moderate amount was observed and it persisted for about three months. The crop was harvested 12 months after plant-

[1]Contribution from Bioproducts Department, The Dow Chemical Company, Midland, Michigan.

ing. Yield of raw cane and sugar was as shown in Table 2. Significant yield increases were obtained with DAXTRON at 0.5 or 1.0 lb/A but the two pound rate was injurious. This result in light sandy loam was in direct contrast to the lack of injury or chlorosis where DAXTRON was used in the loam soils typical of most cane growing areas of Colombia.

Post-emergence directed sprays have been evaluated in a limited number of trials in the Cauca Valley. In one experiment with plant cane 3 to 4 feet tall, a directed spray was applied to the entire area between the rows including the lower leaves and stems of the sugarcane. Goosegrass *(Eleusine indica)* in flower was the major weed present. Rates used were 1.25, 2.5 and 5.0 lb/A.

Excellent kill of goosegrass was obtained within 15 days with all dosages. Burn of the lower leaves of the cane was observed with all treatments. Chlorosis of the cane was observed with all rates and ranged from slight at 1.25 lb/A to severe at 5.0 lb/A. Leaf discoloration appeared about 15 days after spraying and persisted about two months at the lowest rate.

The crop was harvested six months after applying the herbicide. Yield data are presented in Table 3. While yields were low due to early harvest, the data indicate that rates of 2.5 lb/A or less were not deterimental to yield of cane or sugar but the 5 pound rate was injurious. Weed competition was not a factor detrimental to yield.

During 1965 and 1966 DAXTRON herbicide was evaluated for weed control in sugarcane in Trinidad at the Tate and Lyle Central Agricultural Research Station. Working mainly on heavy soils, Davies (1,2) has reported excellent residual control of both annual grasses and broadleaved weeds with pre-emergence applications of 1 to 2 lb/A in plant cane with little or no injury to the crop (Table 4). Combinations of 0.5 to 1.0 pound of DAXTRON plus 0.5 lb/A of TORDON herbicide have given good pre-emergence control of most annual species for a period of three to four months. Overall post-emergence applications at 1 to 2 lb/A to ratoon cane also provided good weed control but caused severe temporary chlorosis of the cane.

Results on Louisiana sugarcane for the control of johnsongrass seedlings *(Sorghum halepense L.)*, the major weed problem in that area, have been especially promising. Used alone or in combination with TORDON herbicide applied pre-emergence to plant cane in the fall or pre-emergence in

Table 1. Weed control with pre-emergence herbicides in plant cane growing in clay loam soil. Cauca Valley, Colombia, 1966.

		Percent ground cover-days after application		
		58 Days		96 Days
	lb/A	Annual[(a)] Grasses	Broadleaved[(b)] Weeds	Mixed[(a&b)] Weeds
Untreated	–	42	54	100
DAXTRON	0.5	2	30	52
	1.0	0	14	34
	1.5	0	8	28
diuron	3.0	2	8	24
atrazine	3.0	10	4	24

(a) Grass genera: *Eleusine, Echinochloa, Panicum* and *Digitaria.*
(b) Broadleaved weed genera: *Euphorbia, Solanum, Commelina* and *Sida.*

Table 2. Control of *Eleusine indica* with pre-emergence herbicides and yield of plant cane grown in sandy loam soil. Cali, Colombia, 1966.

		Percent Ground Cover		Yield	
	lb/A	After 48 Days	After 100 Days	Cane T/A	Sugar T/A
Untreated	–	100	100	28.6	2.50
DAXTRON	0.5	4	34	71.4**	6.22**
	1.0	0	10	74.1**	7.12**
	2.0	2	10	49.3	4.65
diuron	2.0	8	66	77.5**	7.55**
	3.0	0	40	60.4**	4.50
atrazine	2.0	24	100	65.4**	6.06**
	3.0	20	74	66.5**	5.20**
LSD 1%				31.2	2.35

Table 3. Sugarcane yield following directed postemergance applications of Daxtron to plant cane growing in sandy loam soil. Cali, Colombia, 1966.

		Yield				
	lb/A	Cane T/A	Sugar (%) in Raw Cane	Brix	Purity (%)	Sugar T/A
Untreated	–	42.0	7.78	15.25	80.98	3.27
DAXTRON	1.25	38.1	8.56	16.65	81.40	3.26
	2.5	44.2	8.07	15.97	80.00	3.57
	5.0	34.1	7.75	15.77	78.99	2.65

Table 4. Results expressed as percent ground cover* with pre-emergance herbicides in plant cane growing in Freeport clay soil, Trinidad.

	Rate Active Ingredient lb/A	Waterloo Estate 60a Number of Days After Application		Waterloo Savannah 1 Number of Days After Application	
		111	129	47	111
Untreated	–	33	80	10	60
DAXTRON	0.5	7	20	7	13
	1.0	3	17	0	7
	2.0	0	3	0	7
DAXTRON + TORDON	1.0 + 0.5	0	0	0	5
TORDON	0.5	3	7	10	27
atrazine	2.5	10	20	0	13
Accumulated rainfall (inches)		12.6	16.9	2.0	12.6

*Dominant weed species was the perennial grass *Sporobolus indicus.*

early spring to plant or ratoon cane has given good control of seedling johnsongrass and most annual species without injury to the crop. Combinations of DAXTRON and TORDON at the broadcast rate of 1.5 lb/A of each have been safe and effective in Louisiana and are under intensive study at this time. These applications are made as over-the-row band treatments covering one-third of the area and, therefore, one-third of the above dosage is applied per crop acre.

In Hawaii, good control of annual grasses and broadleaved weeds has been obtained with pre-emergence applications of 1 to 2 lb/A. Residually, Daxtron herbicide has been more effective on grasses than broadleaved weeds. Injury ratings reported were slight to moderate at the lower dosage levels. Presumably this was a chlorosis effect. No yield data have been reported. From the data obtained elsewhere it appears that chlorosis may be more pronounced in cane grown in highly leachable Hawaiian soils than in heavy soils typical of many other cane growing areas.

In summary, Daxtron shows considerable promise for pre-emergence use in sugarcane even though some temporary chlorosis may occur on coarse textured soils. Overall post-emergence sprays probably are too injurious to the crop. Further work is needed to determine the feasibility of directed post-emergence applications. In some areas resistant broadleaved weeds may prove troublesome and combinations with other herbicides may be needed to handle them.

Bananas

Bananas have exhibited very good tolerance in tests conducted in Colombia, Jamaica, Guadeloupe and Hawaii.

In one Colombian test, conducted on sandy loam soil near Cali, Daxtron herbicide was applied pre-emergence to the weeds at rates of 0.5 to 2.0 lb/A as a directed ground spray under five month old Gros Michel bananas. Effective residual control of annual weeds was obtained for 143 days with 1.0 lb/A. Slight temporary chlorosis was observed on a few leaves with the 2.0 lb/A treatment. Fruit development and plant growth, as observed 112 days after spraying, appeared normal with all treatments.

In Jamaica and Guadeloupe rates of 1.0 to 2.0 lb/A applied under bananas have given excellent control of annual broadleaved weeds and grasses for two to three months without any apparent injury to the crop. The more tolerant weed species encountered in these countries were *Paspalum conjugatum, Commelina diffusa, Ipomoea spp., Panicum purpurascens* and *Tradescantia fluminensis.*

African Oil Palm and Coconut

Preliminary crop tolerance trials have been conducted at Cali, Colombia on 3-year old African oil palm and coconut growing in sandy loam soil in which applications were made as a directed spray around the base of the plants. No chlorosis or adverse growth effects occurred at 4.5 lb/A, the highest rate applied. In pre-emergence applications annual grasses were controlled for 90 days at rates of 0.75 lb/A or more. Post-emergence treatment at 1.5 lb/A applied as a directed spray to annual grasses in the tillering stage provided good control for 54 days. The 3.0 lb/A rate gave good control for three months.

Coffee

The tolerance of 3-month old coffee plants of the Colombian Typica and Caturra varieties to directed sprays was studied in a preliminary trial at Cali, Colombia. These plants were grown in sandyloam soil under platano shade. Both varieties responded similarly. One pound per acre caused only a trace of chlorosis, while higher rates resulted in moderately chlorotic leaves. Further research is needed to determine whether DAXTRON herbicide can be used safely in this crop.

Peanuts

Daxtron herbicide has been evaluated in the major peanut growing areas of the United States and intensive studies are continuing. Very promising results have been obtained with pre-emergence applications of 0.4 to 0.5 lb/A for the control of annual weeds. Slight to moderate temporary chlorosis of the peanuts has been observed in some trials. However, plants have recovered completely within two to four weeks after emergence and yields have not been reduced.

Pineapple

Tolerance trials have been conducted in Colombia, Puerto Rico and Hawaii. Some varieties appear tolerant to overall sprays soon after planting of rates up to 2.0 lb/A. Higher rates as directed sprays have been tolerated well. Further research is warranted with preplant, overall and directed applications. Differences in varietal response should be investigated further.

Rubber

Hevea rubber trees are very tolerant to Daxtron herbicide applied as a directed spray. It not only kills existing vegetation but prevents re-establishment of seedlings for several weeks. A program worked out in Malaya consisting of an initial application of 2.0 lb/A followed by one or two follow-up applications at the same dosage at intervals of three to four months has given good control of most species for a 12-month period. Some of the more tolerant genera encountered include *Lygodium, Gleichenia, Scleria* and *Paspalum*. The addition of TORDON herbicide at 0.2 lb/A has significantly increased the control of broad-leaved species. Further research is needed.

SUMMARY

A new herbicide, 2,3,5-trichloro-4-pyridinol has shown considerable promise for use in tropical agriculture. At rates of 3 to 20 lb/A it is a broad spectrum herbicide and has utility for general vegetation control in noncrop areas. Crops which have been found tolerant to rates of 0.5 to 2.0 lb/A applied pre-emergence, preplanting or as directed sprays include sugarcane, peanuts, bananas, African oil palm, coconut, rubber, pineapple and coffee. Research is continuing for all of these uses.

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'GRAMOXONE' : ITS PROPERTIES AND PLACE IN ASIAN AGRICULTURE

G. A. Watson[1]

'Gramoxone' contains paraquat, 1,1'-dimethyl 4,4'-dipyridylium dichloride, a weedkiller discovered by I.C.I. Ltd. and is now used in Asia on a large scale as a general herbicide for tree row weeding in Malayan rubber plantations. 'Gramoxone' has, however, a number of properties which make possible its use in a wide range of techniques, from aquatic weed control, crop desiccation and selective weeding in legumes, to its application for pre-planting weed control in a variety of crops, replacing all or some of the cultivations normally carried out for this purpose. In Asia weeds often present a severe limitation to agricultural production and improved, economic methods for their control are urgently required. To determine where 'Gramoxone' can best assist in this problem its particular properties need to be considered.

TOXICOLOGY

The undiluted formulation of 'Gramoxone' has an acute oral toxicity (LD50) to rats of 633 mg/kg, while that of a spray solution of 2 pints in 20 gallons is 52.4 g/kg. Provided that reasonable precautions are used in handling the concentrate, the chemical is therefore one of low toxicity that can be handled safely by untrained operators.

Used at normal rates, 'Gramoxone' is harmless to fish, and can be used for aquatic weed control, while cattle have safely grazed for 4 weeks treated pasture carrying initially 400 ppm of 'Gramoxone' residue. In these animals very low levels of paraquat were detected in the urine, and relatively high levels in the feces, indicating very poor absorption from the gut.

ACTIVITY

'Gramoxone' is mainly dependent upon light, chlorophyll and oxygen for its activity, indicating that the photosynthetic process of plant is involved. After its absorption into the plant a stepwise reduction takes place giving a free bipyridyl radical which is then reoxidised by molecular oxygen leading to the formation of peroxide radicals or hydrogen peroxide by a series of chain reactions; it is these peroxide units which are thought to produce the characteristically rapid toxic effect of 'Gramoxone', obvious within a few hours of application. Some similar but much slower killing reaction can be associated with the respiratory action.

As a consequence of this mode of action 'Gramoxone' has a much slower effect during the dark, and, more importantly, will not affect brown bark and corky or lignified tissue. The chemical can accordingly be sprayed quite safely on the brown stems of plants and trees, a safety factor of great importance.

PHOTOCHEMICAL DECOMPOSITION AND INACTIVATION

Modern research is producing many types of residual soil-acting herbicides that are of particular value in one-crop systems and where sophisticated farmers are concerned. However, most Asian farmers are not sophisticated in the use of agricultural chemicals, and many of the more productive areas grow a variety of crops. Under these circumstances, and particularly bearing in mind the generally small size of individual holdings where every square yard needs to be kept under cultivation, any chemical that is to be introduced needs to have a very high safety factor with regard to residual effects. 'Gramoxone' is such a chemical for three particular reasons.

'Gramoxone' is generally applied at about 0.5 lb a.i. per acre and a portion of this applied chemical is decomposed by the action of sunlight on the leaf surface before it ever reaches the soil. In bright sunlight as much as two thirds of the applied paraquat can be decomposed in the time taken for the weeds to wither and disintegrate into the ground, the end products being carbon dioxide, methylamine (which is found naturally in plants) and N-methyl quaternary isonicotinic acid (abbreviated to QINA). The last is a substance of very low toxicity which is decomposed very rapidly in soil.

In the United Kingdom it has been found that successive annual sprays of 1 lb/acre of paraquat have not led to any increase in the levels of paraquat in the soil. This must be at least partially due to micro-biological decomposition, since it is believed that soil adsorbed material is not decomposed photochemically, there are no losses by volatilisation; and leaching losses are small due to adsorption in the soil. Paraquat contains 11% of nitrogen and a large number of bacteria have been found capable of decomposing small amounts of the chemical. A common soil yeast, *Lipomyces starkeyi* is particularly efficient, decomposing the paraquat to give nitrate and carbon dioxide as end products.

The third and greatest safeguard in the use of 'Gramoxone' is the very large capacity of normal mineral soils to adsorb and inactivate paraquat. On contact with the soil, either directly or by transfer from sprayed and dead vegetation, the paraquat ions are almost immediately adsorbed onto the soil particles and then with time move into positions within the clay complex where they are so strongly bound that only boiling with sulphuric acid will displace them.

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[1]Contribution from Plant Protection Limited, Fernhurst, England.

Laboratory tests have been carried out on two soil types common in Asia, a low humic gley soil of the Selangor series, and a lateritic soil of the Malacca series, both from Malaya. The clay mineral of the former is dominantly montmorillonite and of the latter, kaolinite, and it has been shown that they will respectively inactivate 1600 and 250 lb/acre of paraquat in their surface inch, sufficient to accomodate 3200 and 500 applications of 'Gramoxone' at the rate of 0.5 lb.a.i./acre. Allowing for photochemical decomposition after spraying, microbiological decomposition and mechanical distribution down the soil profile, it is evident that risks of residual toxicity developing in the soil are negligible.

With its rapid and effective action against all green tissue, and its safety in use, 'Gramoxone' has wide application in a number of techniques and many crops in Asia.

THE USE OF 'GRAMOXONE' IN CONVENTIONAL METHODS OF WEED CONTROL

Plantation crops.

'Gramoxone' is used to a major extent in the rubber plantations of Malaysia, largely for weed control along the tree rows in young rubber. The chemical is proving to be an economic and safe alternative to sodium arsenite and a number of techniques have been developed to widen its use. For instance, in mature rubber applications of 1½-2 pints of Gramoxone per acre should give satisfactory weed control. In young rubber, however, the greater light intensity both permits more vigorous weed growth and also quickens the speed of action of the 'Gramoxone', abbreviating the period of leaf absorption and lessening overall kill. Under these circumstances the stoloniferous grass *Paspalum conjugatum* shows rapid regeneration and can become a dominant, troublesome weed. *Paspalum conjugatum* is, however, sensitive to Weedazol TL applied at 4 pints/acre, and it has been found that if a sub-lethal dose of 2 pints/acre of this chemical is applied followed after an interval of 3 weeks by 'Gramoxone' at 2 pints/acre, then a prolonged control of 3-4 months is achieved (Headford, 1966, Bellis, 1966). In similar fashion, although the ubiquitous *Imperata cylindrica* can be rapidly, desiccated by 'Gramoxone', repeated applications are required for eradication and an alternative technique, developed in Malaya and Thailand, is to first spray with 8 lbs./acre of dalapon in 80 gallons of water then follow after a 4 weeks' interval with 'Gramoxone' at 2 pints in 40 gallon/acre. The latter technique is effective and more economic than the generally accepted recommendation of 15-20 lbs/acre of dalapon in 100-120 gallons of water.

With its safety towards brown bark 'Gramoxone' can be used safely in rubber, almost from the time of planting onwards and this property may lead to the development of low cost, extensive planting of rubber. In this system the only land preparation will be to clear strips through the existing vegetation, the rubber will be planted, and thereafter the only maintenance will be to keep the weed sufficiently in check with 'Gramoxone' to prevent any limitation on tree growth. Sufficient levels of fertilizer can be added to compensate for any deficiencies of the natural vegetation compared with the legume covers normally planted, and the method may prove attractive to authorities faced with the problem of replanting large areas of rubber quickly and cheaply.

In addition to rubber, 'Gramoxone' on its own, or in mixture or sequence with translocated herbicides, is now commonly used in oil palm in Malaysia, in citrus in Japan, tea in India and Ceylon, and bananas and hard fruits in Australasia.

The chemical may also prove to be a useful tool in the Philippine sugar cane plantations following its use in Mauritius and the West Indies. In plant cane 'Gramoxone' can be applied overall at 1 - 2 pints/acre a few days before cane emergence, and is often used in mixture with MCPA or residual herbicides for inter row weed control using low drift equipment.

Smallholding food crops.

In Asia food crops are grown under a variety of conditions, ranging from the most primitive form of shifting cultivation in cleared jungle, to intensive irrigated bed culture of vegetables grown for nearby cash markets. The low productivity of the former will not permit use of chemicals, but in the latter system fertilizers, insecticides and fungicides are in common use. Weeds are generally kept under control by hand methods but as living standards improve labour costs will rise and there will be an increasing need for herbicides. This position has already been reached in certain parts of Malaya where farmers are now using 'Gramoxone' to spray beds clear of weeds before sowing each crop of vegetables.

In a number of countries attempts are being made to raise food production by clearing jungle in large, state-aided schemes, and settling people into the area to grow paddy rice, maize, sorghum, vegetables and other crops. With minimal mechanical assistance these people face a forbidding task in attempting to build up a productive agriculture; one of their biggest problems is to maintain control of invading weeds and with *Imperata cylindrica* ever present they cannot be envied. Experience in Africa and Asia shows that one family can only maintain less than 5 acres weed free and in useful production, placing an automatic restriction on their prospects for improvement. To provide these settlers with adequate conventional cultivation equipment for pre- and post-planting weed control would involve immense capital expenditure, and probably be beyond Government resources. Knapsack sprayers and the non-residual 'Gramoxone' could, however, be supplied for a much lower cost, and yet be a powerful tool for the farmer.

'Gramoxone' could be used for preplant weed control, eliminating some or all of the cultivations normally carried out for this purpose and so permitting available machinery to operate over greater acreages. The chemical could then also be used for post-planting weed control using shielded low drift spray nozzles. In maize and sorghum, particularly, work in Europe and the Americas is showing that 'Gramoxone' can be safely applied inter-row, using shielded sprayers, once the plants have reached a height of 18 inches and their base is protected by dry leaf sheaths.

Aquatic weeds.

In most Asian countries aquatic weeds present a problem in both natural and artificial waterways, reducing the delivery of irrigation water and interfering with drainage, and fishing resources. Since any adverse effects they may have on crop production are not easily assessed, and since Governmental action is required to institute effective, integrated control measures, it is only in extreme cases that anything has been done about this problem. In Ceylon, *Salvinia auriculata* has been a pest for some time, infesting irrigation "tanks" and paddy fields and 'Gramoxone' has been used effectively in official spraying programmes to control the weed. A similar problem exists in Kerala, India, but elsewhere the water hyacinth, *Eichornia crassipes,* and water lettuce, *Pistia stratiotes,* present the major floating weed problem. These, and emergent weeds such as *Phragmites, Typha* and *Cyperus* spp., as well as certain submerged weeds and algae can all be controlled by 'Gramoxone'.

Before any effective action against these weed problems can be expected on a national scale, however, surveys will be needed to determine the extent to which crop production is affected, in order to justify the costs of necessary control measures. It must also be accepted that these control measures will need to include not only the initial spraying, but a long-continued period of surveillance by resident spray teams to prevent any serious regeneration.

THE USE OF 'GRAMOXONE' FOR CROP DESICCATION

With its very rapid action on the green leaf and limited translocation 'Gramoxone' and its sister chemical 'Reglone' (diquat) are most effective desiccants. In Latin America where mechanical rice harvesting is sometimes interfered with by bad weather 'Reglone' has been used to desiccate the standing crop; provided that the crop is then picked up within a few days of spraying, and is not subjected to frequent re-wetting, an improved harvest results.

In sugar cane 'Gramoxone' can be used to desiccate the cane to facilitate burning prior to mechanical harvesting. In a related technique, Nickell and Tanimoto (1964) have found that spraying with 'Reglone' at the time of flower initiation will check the cane and prevent it flowering; the cane then resumes vegetative growth and an improved yield of sugar results. Spraying with a low rate of 'Gramoxone' will also give tassel control and this technique is presently being studied in the Philippines, Mexico, Peru and other countries.

In Europe and America the bipyridyls are used for the desiccation of potato haulms at harvest, cotton defoliation and desiccation, and the desiccation of seed crops prior to harvest. All these uses are linked to mechanical harvesting methods and perhaps of greater relevance to the immediate Asian situation is the use of 'Gramoxone' to assist in the replanting of old pineapples. Normally on larger estates the old bulky vegetation is chopped and incorporated into the ground with the help of massive machinery, but this is not possible on the smaller holdings. An effective alternative, however, is to desiccate the old plants with 'Gramoxone' applied at 4 pints/acre and burn off and replant. In Formosa this technique is enabling the farmer to speed his replanting and make more effective use of the limited ground available to him.

THE USE OF 'GRAMOXONE' IN MINIMAL CULTIVATION TECHNIQUES

Wheat. In many places in Asia and Australasia, cereal crop production is limited by the time available for cultivation. In Western Australia for instance, the land is cultivated and seeded during the short rainfall 'breaks' of that area, and in a very short 'break' only a limited amount of land can be prepared for planting. Under these conditions any increase in the rate of land preparation automatically means increased crop acreage and yield, and minimal cultivation techniques are now being developed to meet the situation. In these techniques the flush of weeds germinating on the 'break' are eradicated by an application of 'Gramoxone' and then wheat is slot seeded directly into the uncultivated soil.

Rice. In Queensland slot-seeding is also being carried out in rice cultivation, with pre-sowing and pre-emergence grass weeds kept under control by grazing with sheep. There would seem to be no reason why this technique should not also be useful elsewhere in Asia, where the soil type is suitable, with 'Gramoxone' being used for weed control in place of the sheep.

The most convincing advances in this direction are found in Japan where 'Gramoxone' is being used to eradicate *Alopecurus* spp. and *Eleocharis* spp. weeds prior to rotovation and seeding. The Central Rice Research Institute at Konusu has shown that following treatment with 'Gramoxone' it is possible to reduce the number of cultivations required to make a dry seed bed from as many as 3–4 rotovations, depending on the weed density, to only one.

The use of 'Gramoxone' as an aid to cultivation is now being officially recommended for weed control prior to the formation of nursery beds in the Hokuriki, Tokai-Kinki and Chugoku districts, and it is easy to visualise the extension of the principle to the crop as a whole.

In the less advanced rice growing areas of Asia the need for improved methods of land preparation is even greater than in Japan. Several Governments are straining their resources to provide the tractors and implements thought to be necessary for adequate land preparation and yet, when it is considered that the main single reason for cultivating the land is that of weed control, one wonders whether these represent the best and only tools? There are in fact many reasons for feeling that chemical herbicides, and particularly 'Gramoxone', can partially or wholly replace this mechanical requirement and are likely to play an increasingly valuable role in rice cultivation in the future.

Two examples can be quoted which illustrate the time and labour saving advantages of the chemical technique. In certain parts of Malaya paddy farmers also own rubber smallholdings or find part-time employment on rubber or oil palm plantations. One method of preparing the fields for planting entails slashing of the weeds, followed by flooding for a period of 3–5 weeks during which the slashed weeds rot. The weeds are then raked on to the bunds and paddy seedlings are transplanted into the soil without further treatment. To leave their normal employment for this arduous work is not attractive and hired labour can be expensive. An alternative, cheaper method has been demonstrated in which weed growth is first desiccated by an application of 'Gramoxone' then burnt off after 3–5 days following which the field is flooded and paddy seedlings immediately transplanted. This technique can be completed in a week and presents positive and immediate advantages over the old method.

The second example comes from Ceylon, where the farmers are now ahead of the research worker in developing the technique, a tribute to its great potential. For a number of years 'Gramoxone' has been used under Government subsidy to eliminate *Salvinia auriculata* from waterways and infested paddy fields prior to planting. The farmers have seen that as well as killing the *Salvinia* the chemical has also killed other weeds and greatly facilitated subsequent cultivation of the field. This has been taken advantage of at Bombuwela Rice Research Station in the Wet Zone of Ceylon where the manager, for two successive crops in 1966, sprayed his entire station of some 20 acres with 'Gramoxone', trod the dead vegetation into the flooded soil with the buffaloes, and then broadcast seeded his paddy. Post planting conditions were superior to those normally achieved following two ploughings and a 'puddling'.

The two major advantages of the chemical technique are the saving of cultivation time, which can effectively lead to the use of longer duration varieties and greater flexibility in the cropping schedule, and a saving of the excessive pre-planting water usage with normal methods of land preparation.

Chemical techniques of land preparation in rice cultivation are now being actively developed in Ceylon, Malaya, Japan and the Philippines. If their early promise holds good it may be that we can leapfrog the clumsy mechanical age when brute force combats intractable ground conditions, and use instead an efficient, modern tool more suited to the problems and the farmers concerned. In his battle to control weeds and grow satisfactory crops under, at times, arduous climatic conditions, the Asian farmer has so far been able to rely only on his own hands, his buffaloes or the infrequent tractor. The task, coupled with lack of incentive, has been perhaps too much for him to exert additional effort over that required to obtain a subsistence living. However, as his demands grow, stimulated by outside pressures, he will need to increase his productivity and in the absence of massive mechanisation will turn to chemical herbicides to ease his work. The use of 'Gramoxone' in this type of farming is still at the early development stage but seems certain to expand.

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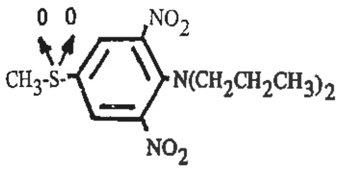
SD 11831 – A NEW HERBICIDE FROM SHELL

W. J. Hughes – R. H. Schieferstein[1]

INTRODUCTION

SD 11831 is a new herbicide developed by Shell that is being sold as PLANAVIN* Herbicide.[2] Chemically it is 4-(methylsulfonyl)-2,6-dinitro-N,N-dipropyl aniline, having the following structure:



SD 11831 forms rectangular prism-type crystals and in the pure state is light golden-orange in color with a melting point of 151–152°C. The vapor pressure is very low, being less than 1.5×10^{-6} mm of mercury at 25°C. At this temperature the water solubility is 0.6 ppm. Solubility in acetone is 36%, dimethyl sulfoxide 33%, and 2-nitropropane 25%. SD 11831 is poorly soluble in common hydrocarbons, alcohol and aromatic solvents. It is currently being sold as a 75% wettable powder, although a 4 pound per gallon liquid suspension is being evaluated.

[1]Contribution from Agricultural Research Division, Shell Development Company, Modesto, California.

[2]Samples for testing in the United States, Hawaii and Puerto Rico can be obtained from: Shell Chemical Company, 110 51st Street, New York, New York 10020.

[3]Dosages are in terms of active ingredient.

Field Performance

SD 11831 has been evaluated the past three seasons by many cooperators in many types of pre-emergence treatments. In sandy soils, rates of 0.5 lb/A[3] have given good weed control; 0.75–1 lb/A have generally given effective weed control on loamy type soils throughout the cotton belt in the United States. Weeds in heavier textured soils that are reasonably low in organic matter (5%) have required 1–1.5 lb/A, while the black soils in the North Central region of the U.S. may require rates greater than 2-3 lb/A. This increased rate requirement is due in part to absorption by the organic matter making less of the applied dosage available. Also, these soils appear to have a greater capacity for inactivation of the herbicide through biodegradation. The chemical has generally been most effective when incorporated in the surface inch of soil. Deeper incorporation has tended to reduce effectiveness at the lower rates, probably due to dilution in the soil. Normal cultivation with sweeps or chisel shanks that stir rather than invert the soil has not affected herbicidal activity. In fact, cultivation can remove tolerant broadleaved species which, when cut off and brought up into the treated zone, fail to re-establish even under ideal moisture conditions.

Pre-emergence surface applications have, at times, been as effective as preplant incorporated treatments. Their effectiveness appears to correlate with the interval between chemical application and the first rain. Rain, no doubt, causes shallow penetration, but also appreciably lowers surface soil temperatures and thus prevents or delays losses from the soil. In areas and seasons where rains are frequent, SD 11831 may be effectively used without mechanical incorporation. Overhead sprinkling has also been sufficient to incorporate the chemical.

SD 11831 has been registered for use on cotton, soybeans and turf, and registration is proceeding for its use on other large seeded legumes, transplanted crops and safflower.

A 1966 test on drilled rice in Arkansas may be of interest. SD 11831 was applied at the time of drilling, then flushed with water to insure uniform germination. Excellent watergrass control was obtained at 1 lb/A, and although temporary stunt was observed at 2 lb/A, no reduction in yield occurred. Excellent results have been reported from Japan where PLANAVIN herbicide has been used on paddy rice.

Crop Tolerance

The selective tolerance of SD 11831 by various crops and certain weeds can result from a degree of inherent physiological or biochemical tolerance or simply from escape due to immobility of this compound in the soil. Beans (pinto variety) grow normally in 12 ppm of SD 11831 mixed throughout a sandy loam soil. Grape cuttings have also shown a high degree of inherent tolerance. Several varieties have been found to root normally in treated soil (van Overbeek, in press). These appear to be examples of biochemical selectivity.

Seeds having well-developed embryos with large numbers of unexpanded cells in the radicle can, upon germination, make considerable root growth without further cell division. This can put the root tip out of the zone of the chemical in soil where it can subsequently make normal growth. Cotton and soybeans, for example, have this capacity in addition to some inherent tolerance. There is an apparent time lag for the root to be affected. Even at very high concentrations, under optimum growth conditions, one to three days may be required to arrest root tip growth. During such a period in the field, a cotton or soybean root could elongate appreciably and escape the chemical if incorporation is not too deep. This appears to be the result of the time required for the herbicide to diffuse to the meristematic cells and to accumulate in effective concentrations. When conditions for root growth are optimum, it is possible for root tips of larger diameter literally to grow away from or outrun the herbicide. If, however, low temperatures greatly reduce growth rate and bio-inactivation rate in the root cortex tissue, inhibitory concentrations may accumulate in the meristem cells of normally resistant root tips. In most species, including many tolerant ones, SD 11831 stops lateral roots before they get started. This results in the so-called "root-pruning" of laterals in the soil zone where the herbicide is present.

Since SD 11831 is effective even when restricted to a shallow zone at the soil surface and does not leach readily, it can be used safely on most deep-seeded, transplanted and established perennial crops, even though they may be inherently very sensitive. In these cases the depth of incorporation should be governed by the depth of the crop seed placement or the weeds that might be present in the case of the established crops.

Some crops in which SD 11831 is potentially useful are:

Cotton	Lima beans
Soybeans	Various crucifers
Peanuts	Blackeye peas
Safflower	English peas
Alfalfa	Watermelons
Field beans	Rice
Carrots	Caneberries
Red Clover	Tree crops
Potatoes	Turf
Bell peppers	Nursery stock
Sweet potatoes	Tobacco
Grapes	

HERBICIDAL ACTIVITY

The mode of action of SD 11831 appears to be the inhibition of plant cell division. Species vary considerably in the concentrations required to inhibit root growth. Wheat root growth, which is inherently quite sensitive, is completely inhibited by 6×10^{-8} M SD 11831 in solution culture. This is approximately 0.02 ppm. More tolerant species require higher concentrations for inhibition and, as with cotton, may show a time lag for the onset of inhibition.

Cell elongation does not appear to be inhibited by SD 11831. On the contrary, a swelling appears at the tips of affected roots in most species. Although histological examination shows large cells in what is normally the meristematic region, further work remains to elucidate the mode of action.

As the previous attention given to root growth would imply, SD 11831 is primarily a pre-emergence herbicide. Since it is active on cell division, it must be placed in the zone where the weed seeds germinate and growth starts in order to be effective. Most weedy grasses are highly sensitive. Some of the species most easily controlled are watergrass, *Echinochloa crusgalli;* crabgrass, *Digitaria* sp.; foxtails, *Setaria* sp.; witchgrass, *Panicum capillare;* annual bluegrass, *Poa annua;* and annual ryegrass, *Lolium multiflorum.* Under ideal conditions in sandy soils these species are controlled at rates of 0.25 lb/A and less. For practical purposes, however, 0.5 to 1 lb/A will be required. Many broadleaf species are also controlled as seedlings at these rates. These include fiddleneck, *Amsinckia douglasiana;* curly dock, *Rumex crispus;* plantains, *Plantago* sp.; dead nettle, *Lamium amplexicaule;* bull mallow, *Malva nicaeensis;* and purslane, *Portulaca oleracea.* Species having a little tolerance and requiring 0.75 to 2 lb/A for control are downy brome, *Bromus tectorum;* wild oats, *Avena fatua;* pigweed, *Amaranthus* sp.; lambsquarters, *Chenopodium album;* prickly lettuce, *Lactuca scariola;* shepherdspurse, *Capsella bursa-pastoris;* groundsel, *Senecio vulgaris;* knotweed, *Polygonum aviculare;* cress, *Lepidium* sp.; and others.

Weeds not adequately controlled at dosages of 1–2 lb/A include certain nightshades, *Solanum* sp.; mustards, *Brassica* sp.; smartweeds, *Polygonum* sp.; ragweed, *Ambrosia artemisifolia;* and velvetleaf, *Abutilon theophrasti.* Established perennial weeds and deep germinating species such as cocklebur, *Xanthium pennsylvanicum,* are also resistant.

When sprayed post-emergence on the foliage of plants, SD 11831 causes temporary stunting. The recovery of shoot bud growth would indicate that the initial dose taken up by the meristem is detoxified and not replenished by translocation from the rest of the plant. Post-emergence applications appear to be effective only on crabgrass seedlings. If the application is made to young seedlings in the two-leaf stage with undeveloped roots, development is completely arrested and the seedlings eventually die.

SOIL RELATIONSHIPS

Understanding the action of pre-emergence herbicides in the soil has recently been greatly aided by measurement of certain physico-chemical parameters. The partition coefficient (Kp) of a chemical between soil and water has been studied for some time (Sherburne et al, 1954); results varied widely between soils and were of limited value. When, however, the distribution coefficient between soil organic matter and water (Kp (om/w) was studied, it was found that there was little change in the Kp (om/w) of non-ionic compounds in soils ranging from 0.25% to 40% organic matter (Lambert et al, 1965). With SD 11831, the Kp (om/w) has been found to be in the range of 400 to 500 compared to about 70 for diuron. The leaching rate and application rate requirement of a compound are dependent in the main on this distribution ratio. It is thus useful in predicting performance in soil where organic matter and water contents are known.

Leaching rate varies inversely with KP (om/w) and thus SD 11831 is not readily displaced by percolating water. It has been found to move only about ½ inch in a sandy loam soil with 1% organic matter with three inches of applied water. This is compared to 3.3 inches movement of diuron. SD 11831 would be expected to leach even less in soils of higher organic content. This property is important to "escape selectivity" and to herbicidal activation requirements.

The application rate required for a given response is a direct function of Kp (om/w) and thus higher rates would be required in high organic soils. Tests have shown that on a peat soil, the rate required is over four times that on a sandy loam with 1% organic matter.

The persistence of any pre-emergence herbicide in the soil is important both from the standpoint of length of period of weed control and possible carry-over into subsequent crops. Under moist soil conditions during the cropping season in California half of SD 11831 is lost from the soil in 3[illegible] days. Disappearance rates for SD 11831 have been found to vary with both temperature and moisture content of the soil. In an air-dried soil stored at 22°C, half of the chemical was lost in 54 days.

Loss of a compound from the soil surface is an important consideration for pre-emergence soil active compounds. Factors which can contribute to such loss are volatility, photo decomposition, thermal decomposition, and water vapor co-distillation. Half of SD 11831 was lost after seven days in tests under high sunlight conditions in California in which daytime soil surface temperatures were greater than 55°C. In other tests under similar conditions, delaying incorporation by four days reduced somewhat, the effectiveness of 0.75 lb/A applications on a sandy loam soil. In the same tests, treatments with incorporati[illegible] delayed two days were as effective as those incorporated immediately. In these studies conditions were more severe than would be encountered in normal use practices in most crops, so timing of incorporation should not be even this critical. Because of its low volatility, vapor loss would not be expected to contribute greatly to the loss of SD 11831 from the surface of the soil. However, all of the other factors mentioned appear to be implicated in the loss of this compound. Thus, in the absence of rain, mechanical incorporation is necessary to insure against the loss of chemical from the soil surface.

Based on these considerations one can see that the period of effectiveness obtained with SD 11831 will vary with the rate of application as well as the climatic and soil factors. Prevention of weed establishment for two to three months has been obtained with 0.75 lb/A applications. Regarding carry-over, in California mid-September applications of 3 lb/A injured barley planted the following March 23, while 1 lb/A caused no adverse effect. Neither rate of application affected sugar beets planted six weeks later on May 7. In a sandy loam soil, spring applied treatments of 1 lb/A and under had no detectable effect on barley seeded in the fall following disking. Two and 4 lb/A applications, however, injured the barley. In a similar test applications as high as 2 lb/A had no adverse effect on corn planted a year later following a fall disking and normal seed bed preparation. Four lb/A treatments seriously stunted the corn roots. Thus, for crops treated in the spring, with the summer season for dissipation, carry-over from reasonable dosages should not be a problem.

Available data suggest that SD 11831 will not present any hazard to man or animals. The acute oral LD_{50} for both mice and rats is greater than 5000 mg/kg. Percutaneous acute toxicity to albino rabbits is greater than 2000 mg/kg. Five fish species, bluegill, gambusia, goldfish, trout, and silver salmon, tolerated suspensions of 20 ppm for 48 hours. This is much higher than its solubility in water. No adverse effects are apparent in long term toxicology studies with rats and dogs currently under way.

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THIOCARBAMATE HERBICIDES FOR WEED CONTROL IN VEGETABLES

J. Antognini[1]

The thiocarbamate herbicides were first reported on by Antognini, et al (1) for pre-emergence and post-emergence grass and broadleaf weed control in a number of vegetable, forage and agronomic crops. This group of herbicides possesses two very unique features. First, activity is greatly increased, Antognini, et al (3), Antognini (4), Burt (9), McWhorter, et al (27), with soil incorporation and soil subsurface applications compared to soil surface applications. With soil incorporation and soil subsurface applications results are uniform over a wide range of soil and climatic conditions because activity is not dependent upon overhead water to move the chemical into the required soil zone as is the case with soil surface applications. The second unique feature is that the thiocarbamates are highly active in controlling nutgrass (*Cyperus spp.*) Antognini et al (2), Bandeen (8), Cialone (13), Jordan, et al (26), Rahn (29), Rahn (30), Shadbolt (35), Trevett, et al (37), and quackgrass (*Agropyron repens*) Antognini, et al (2), Carter (10), Everett, et al (19), Furtick, et al (21), Meggitt (28).

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Tolerance of crops to pre-plant soil incorporated applications is quite specific for each of the thiocarbamates. All established crops, (6" – 12" high when crops are direct seeded or after new growth has started in the case of transplanting) however, are highly tolerant to all thiocarbamates.

Tables 1, 2, 3, 4 and 5 summarize the compound designations, chemical identities, crop tolerances, weeds controlled and rates of application of four thiocarbamate herbicides which are used or shortly will be used commercially in various vegetables.

Germination conditions must exist soon after (1–2 weeks) application for control of annual broadleaves.

All grasses growing from seed following treatment are controlled.

In most cases the grasses will germinate, emerge through the soil and develop one or two true leaves before being controlled. Germination conditions need not exist soon after application for control of annual grasses.

Single applications at selective rates will result in seasonal control. For eradication 3 to 4 successive yearly applications of of selective rates or single applications of a non-selective rate (12–18 lbs./acre) are required.

For control of these weeds, the soil must be thoroughly worked prior to application to destroy existing stands.

METHODS OF APPLICATION

Depending upon the crop, method of culture and timing of application, various methods of application may be used to incorporate Eptam into the soil. The permissible interval between application and incorporation is determined by the soil moisture. If the soil is moist, incorporation must be done within minutes following application. If the soil is dry at time of application and remains dry following application, i.e. no rainfall or heavy dew, incorporation can be delayed for hours or days.

There are five basic ways in which the thiocarbamates can be placed into the top 2–3" zone of soil.

1. Discs, or harrow (Pre-plant Applications): The number of discings or harrowings required for proper incorporation will vary with soil type, tilth and moisture. With high forward speeds one discing or 3 harrowings are sufficient.

2. Power driven and ground driven rotary tillers (Pre-plant Applications or Post-

emergence Crop Applications): This type of unit can be used for either broadcast or band applications pre-plant or for between the row applications at lay-by.

3. Cultivation equipment (Post-emergence Crop Applications): Various types of cultivation equipment, if properly used are satisfactory for incorporation at lay-by in such crops as potatoes, Ilnicki, et al, (24) Sawyer, et al (32), Sawyer, et al. (33), Sawyer, et al (34).

4. Subsurface application (At-planting or Post-emergence Crop Applications): Special equipment to inject or layer the thiocarbamates into the soil can be used, Ball (7), McWhorter (27). Injection equipment is designed to place the chemical 1½" deep with 3" between injection points. With application at seeding, the drill row is centered between injection points. The layering equipment places the chemical 3" deep. With all types of sub-surface equipment, either band or broadcast applications can be made.

5. Irrigation water application:

(a) Following soil surface applications – Overhead irrigation is an effective means of incorporating pre-emergence applications into the soil. The irrigation must follow application within the permissible interval determined by soil moisture and the amount of irrigation should penetrate the soil no less than 3" and no more than 6".

(b) As a carrier for the chemical – The thiocarbamates are effective when applied in either overhead or furrow irrigation water. When used in overhead irrigation, the depth of soil penetration of the water should be to a minimum of 3" and a maximum of 6". With furrow irrigation, the chemical should be metered into the water for the entire period that the water is running.

CROP DATA

Sweet and Field Corn, Eptam

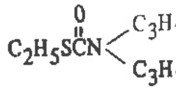
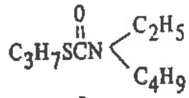
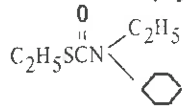
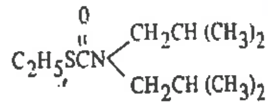
Eptam can be used successfully in corn, Bandeen (8), Chilcote, et al (11), Freeman (20) and Slife (36), if the corn is seeded shallow as found by Dewald, et al (17), Jordan, et al (25), Waidrep, et al (38). Dewald, et al (17) found that the main area of Eptam absorption resulting in phytotoxicity to the corn plant was the stem tissue between the seed and the soil surface. This area is referred to as the "first internode" or "epicotyl". Field experimental data confirmed greenhouse and laboratory findings (Table 6).

Table 1. Compound Designations.

Compound Trade Name	Common Name	Letter Designation	Experimental Compound No.
Eptam®	--	EPTC	R-1608
Tillam®	--	PEBC	R-2061
Ro-Neet®	--	--	R-2063
Sutan TM	--	--	R-1910

®, TM = Trademarks of Stauffer Chemical Company

Table 2. Chemical Identities.

Compound	Chemical Name	Chemical Structure
Eptam	S-ethyl dipropylthiocarbamate	
Tillam	S-propyl butylethylthiocarbamate	
Ro-Neet	S-ethyl ethylcyclohexylethyl thiocarbamate	
Sutan	S-ethyl diisobutylthiocarbamate	

Irish Potatoes, Eptam

Applications to Irish potatoes can be made pre-plant, at emergence and post-emergence up through lay-by by soil incorporation applications or irrigation applications. Both nutgrass and quackgrass have been effectively controlled in potatoes and various studies, Rahn, et al (30), Sawyer, et al (33), have shown Eptam to have no effect on potato yields, quality and storage.

Beans, Eptam

All *Phasoelus vulgaris* beans are tolerant to pre-plant applications of Eptam, Chubb (12), Crabtree (14), Dawson, et al (15), Dawson, et al (16), Dickerson, et al (18), Hartman, et al (23) and Trevett, et al (37). The two main kinds of beans covered are dry beans and green (snap) beans. (Tables 7, 8 and 9).

Table Beets and Tomatoes – TILLAM

Tillam may be applied pre-plant incorporated on both direct seeded and transplant tomatoes, Ashton (5), Ashton (6), Hamson (22) and Ross, et al (31), and on table beets (Crabtree 14).

E. Spinach – RO-NEET

Pre-plant soil incorporated applications have been used on spinach grown for seed as well as spinach grown for the fresh market and processing.

Table 3. Vegetable Crops Tolerant to Pre-plant Soil Application.

COMPOUND	CROP
Eptam	*beans, dry *(Phaseolus vulgaris)*
	*beans, green or snap *(Phaseolus vulgaris)*
	*potato, Irish *(Solanum tuberosum)*
	*corn, sweet *(Zea mays)*
	*potato, sweet *(Ipomoea batatis)*
Tillam	*tomatoes, seeded *(Lycopersicon spp.)*
	*tomatoes, transplant *(Lycopersicon spp.)*
	**beets, table *(Beta vulgaris)*
Ro-Neet	**spinach *(Spinacia oleracea)*
Sutan	**corn, sweet *(Zea mays)*

*Registered use in the United States.
**Registration in United States pending.

F. Field and Sweet Corn – SUTAN

Sutan can be used as a pre-plant incorporated treatment on corn regardless of the seeding depth of the corn.

Table 4. Weeds controlled.

A. Annual Broadleaves:

COMMON NAME	SCIENTIFIC NAME
chickweed, common	*Stellaria media*
henbit (deadnettle)	*Lamium amplexicaule*
lambsquarter	*Chenopodium album*
morningglory, annual	*Impomea purpurea*
nettleleaf goosefoot	*Chenopodium murale*
nettle, small stinging	*Urtica urens*
nightshade, black	*Solanum nigrum*
nightshade, hairy	*Solanum villosum*
pigweed, prostrate	*Amaranthus graecizans*
pigweed, redroot	*Amaranthus retroflexus*
pigweed, rough	*Amaranthus hybridus*
purslane	*Portulaca oleracea*
shepherdspurse	*Capsella bursa-pastoris*
spurge, spotted	*Euphorbia maculata*

B. Annual grasses:

Major grasses are:

COMMON NAME	SCIENTIFIC NAME
barley, foxtail	*Hordeum jabutum*
barley, volunteer	*Hordeum spp.*
bluegrass, annual	*Poa annua*
canarygrass	*Phalaris spp.*
crabgrass, hairy	*Digitaria sanquinalis*
crabgrass, smooth	*Digitaria ischaemum*
foxtail, giant	*Setaria faberii*
foxtail, green	*Sataria viridis*
foxtail, millet	*Setaria italica*
foxtail, yellow	*Setaria glauca*
Johnsongrass (from seed)	*Sorghum halepense*
junglerice	*Echinochloa colunum*
lovegrass	*Eragrostis spp.*
oats, volunteer	*Avena sativa*
oats, wild	*Avena fatua*
rabbitfoot grass	*Polypogon monspeliensis*
sandbur	*Cenchrus pauciflorus*
watergrass (barnyardgrass)	*Echinochloa spp.*
wheat, volunteer	*Triticum sativum*
witchgrass	*Panicum capillare*

C. Perennial Weeds:

COMMON NAME	SCIENTIFIC NAME
Bermudagrass	*Cynodon dactylon*
Johnsongrass	*Sorghum halepense*
nutgrass, purple	*Cyperus rotundus*
nutgrass, yellow	*Cyperus esculentus*
quackgrass (couchgrass)	*Agropyron repens*

Table 5. Rates of application.

COMPOUND	WEEDS CONTROLLED	LBS./A
Eptam	annual grasses and nutgrass	2 – 3
	annual broadleaves	3
	quackgrass, johnsongrass and Bermudagrass	4
Tillam	annual grasses	3
	annual broadleaves, nutgrass, quackgrass, Johnsongrass and Bermudagrass	4
Ro-Neet	annual grasses	3
	annual broadleaves, nutgrass, quackgrass, Johnsongrass and Bermudagrass	4
Sutan	annual grasses	3
	annual broadleaves, nutgrass, quackgrass, Johnsongrass and Bermudagrass	4

Table 6. Corn injury as influenced by depth of sowing.

EPTAM–LBS/A	DEPTH OF SEEDING	CORN PLANTS INJURED
3	1½	0.7%
3	2½	35.0%
6	1½	2.2%
6	2½	42.0%

Table 7. Pre-plant incorporated application (6 lbs./A) on snapbeans[1]

TREATMENT (JULY 8)	BEAN YIELD LBS/A	% WEED CONTROL (SEPT. 9) NUTGRASS	BROADLEAVES
Eptam only	5046	92	30
Eptam + one hoeing	6457	95	83
One hoeing	3731	5	33
Check	1624	0	0

[1]Trevett (37)

Table 8. Treatment applications to dry beans[1]

YEAR	TREATMENT	LBS./A OF DRY BEANS
1958	Eptam 3 lbs./A	2,908
	Handweeded	2,548
	Not weeded	811
1960	Eptam 3 lbs./A	2,531
	Hand weeded	2,673
	Not weeded	345
1961	Eptam 3 lbs./A	2,946
	Hand weeded	2,756
	Not weeded	1,446

[1]Dawson (16)

Table 9. Eptam applications to dry beans[1]

TREATMENT	LBS./A OF DRY BEANS
Eptam 3 lbs./A	2,117
Eptam 4 lbs./A	2,370
Check (Mechanical cultivation)	1,765

[1]Hartman (23)

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MITSUI'S NEW HERBICIDE "MO"

Takayuki Inoue[1]

In Japan PCP has been extensively used as an effective herbicide in paddy fields. However, its high toxicity to fish and mollusks caused the farmers to look for a new herbicide which was less toxic to fish and mollusks and yet effective on the control of weeds in paddy fields. For many years our company has continued to conduct research and development work for a low fish-toxic herbicide which would replace PCP. We synthesized a number of chemical compounds and have conducted basic tests on them since 1958. In 1963 we succeeded in discovering several herbicidal compounds with less toxicity to fish, and developed them as herbicides. Among these compounds 2,4,6-trichlorophenyl-4'-nitrophenylether proved to have low fish-toxicity on official tests, and it was registered in 1965 as an herbicide whose designation was CNP and trade name MO. In that year we began to market MO herbicide formulated as granules which contained 7% active ingredient. Since then the sales of MO herbicide have been rapidly increasing and in 1967 4,800 tons of MO granular were used in paddy fields because the following features were recognized by farmers.

FEATURES OF MO HERBICIDE

1. Outstanding Weeding Effect

MO is a nonhormonal, contact soil treatment herbicide, used most effectively as a pre- and post-emergence herbicide to weeds in primary growth stage in paddy fields.

2. Complete Safety to Rice Plant

Since MO moves very little in soil and is absorbed very slightly by the roots, rice plants are very tolerant to MO and it can be applied under any soil, water-leakage or weather condition. In addition, MO can be safely used regardless of the temperature because it shows very little variations in activity depending upon the temperature.

3. Low Toxicity

Because MO is extremely low in toxicity to man, animals, fish and mollusks, no special precautions are required for use. Results of toxicology tests are shown in the following data.

(1) Test of toxicity on men and beasts (Abstract of the test result by Kyushu University).

a) Test of LD_{50}

Mouse LD_{50} by percutaneous administration 11,800 mg/kg

Mouse LD_{50} by transperitoneal administration 4,500 mg/kg

Rat LD_{50} by oral administration administration 10,800 mg/kg

b) Test of chronic toxicity

No remarkable effect was observed when the drug was administered to rats for 30 days at daily doses of 10 mg. From the above result, MO may be classified as "practically non-toxic" according to the toxic-terms of Hodge and Sterver.

(2) Test of toxicity on fishes (Abstract of the test resulted by Nagoya University).

The toxicity was measured in carp following the method of Dondroff, et al. (1951).

Test Herbicide	Average length	Average weight	TLm (48 hrs.)
MO	6.8 cm	4.3 g	290 ppm
PCP (Control)	6.8 cm	4.3 g	0.285 ppm

From the above result, it may be concluded that the toxicity of MO to fishes is very low.

4. High Stability

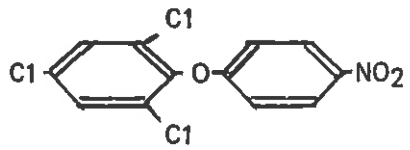
As MO is a chemically stable and non-volatile compound, its herbicidal effect remains over a relatively long period. When used in paddy fields, MO can control weeds for as long as 25–30 days.

MO can be mixed with other agricultural chemicals or fertilizers, because it is neither reactive nor explosive. MO mixtures with BHC, MCP, DBN or prometryne have been developed and marketed.

Physico-chemical properties of MO are as follows:

Chemical Name: 2,4,6-trichlorophenyl-4'-nitrophenylether

Structural Formula:



Molecular Formula: $C_{12}H_6Cl_3NO_3$

Molecular Weight: 318.55

Color and Form: Yellow-brown crystalline powder

Specific Gravity: D_4^{23} 1.6243 D_4^{120} 1.4082

Melting Point: 107° C

Solubility: Soluble easily in benzene and trichloroethylene. Soluble slightly in alcohols, hardly in water.

5. Easy to Use

As MO is odorless, harmless to the skin and does not require drying of paddy fields before application, it can be used easily by anyone.

MO, with the above-mentioned superior features, is available in granular or emulsifiable conceptrate forms. MO granular containing 7% active ingredient is suitable for use in paddy fields. In transplanted cultivation, barnyard grass and other annual weeds are controlled by applying 3–4 kg of MO granular per 10 are at the period of 1–3 days before or 2–6 days after transplanting. In direct sowing cultivation, 3–4 kg of MO granular per 10 are may be applied at the period that weeds are in the primary growth stage after watering.

PRECAUTIONS FOR USE IN RICE

1. Spray the herbicide until the period of simple leaf of barnyard grass, as it is effective by applying in the period from before weed germination through primary growth.
2. Spray the herbicide evenly at the state of filled water in the paddy. Water depth should be maintained 3 cm or more for 3–4 days at least. Do not expose the field surface. Avoid losing water or overflow. Maintain the state of filled water, if the herbicide is applied before rice transplanting.
3. Avoid applying the herbicide in the region where the water fall depth is larger, when the herbicide is applied before rice transplanting.
4. If the herbicide is applied after watering in dry field (direct sowing) culture, remove the existing weeds in the period of dry field, and spray the herbicide as soon

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as possible after filling the paddy with water.

5. Pay attention to spraying the herbicide at the period of abundant weed growth. The amount of the herbicide may be increased according to circumstances.
6. Do not apply the herbicide when the seedling is weak, or the rice plant is moistened by morning dew or rain.

PRECAUTIONS FOR USE IN OTHER CROPS

The herbicide should be sealed up and stored in a dry, cold and dark place.

MO emulsifiable concentrate, containing 20% active ingredient, may be used effectively to protect sobyean, rape, cabbage, lettuce, carrot, burdock and other crops or vegetables against weeds in dry field culture.

1250–1500 cc per 10 are of MO emulsifiable concentrate diluted with 70–100 liters of water should be sprayed over the entire soil surface after seeding, or sprayed on the soil between ridges after implanting.

A. Special Precautions

1. As for soil covering (about 2–3 cm) after seeding, use the soil ground as finely as possible, and press lightly.
2. In that herbicide injury may occur in case of applying at the germinating period of rice, spray the herbicide at 3–4 days before germination.
3. Avoid applying the herbicide in the field where drainage is poor, and when high rainfall is anticipated after spraying, as herbicide injury may occur.
4. The effect may be inferior sometimes at the recommended rates for weeds as *Stellaria media* and *Stellaria ulginosa*.
5. After using the sprayer, wash it well with water.

4 WEED CONTROL IN RICE

COMPETITION BETWEEN RICE PLANTS AND WEEDS

Masao Arai[1]

Weeds cause serious losses, direct or indirect, in the production of crops. It is often pointed out that agriculture is a fight against weeds. The most serious damage to rice by weeds is the decrease of grain yields. It is very important to make clear how weeds damage crops in order to practice weed control and utilize herbicides reasonably and economically.

Weeds adversely affect environmental conditions such as temperature or aeration needed for growth of crops, or harbor plant disease and insect pests which damage the crops. However, the main effect of weeds on crops is the inhibition of growth because of competition for light, nutrition and water.

Since 1955, we have been working to clarify how weeds do damage in rice cultrue. This report is on the mechanism of competition between the rice plant and a few kinds of weeds and on the analysis of damage to the rice plant.

COMPETITION MECHANISM AMONG DIFFERENT WEED COMMUNITIES IN TRANSPLANTED RICE CULTURE

(1) When competition begins:

When two or more plants are growing together, they generally compete with each other for water, nutrients or light. However, we can ignore the competition for water in paddy rice culture.

The competition between the rice plant and weeds for light and nutrition does not begin at the early growth stage of transplanted rice. Experiments have shown that at the early growth stage, the weight of rice plants was the same in no-weed and in weedy plots and the total weight of rice and weeds in the weedy plot was more than in the no-weed check. It would appear from the results of several experiments that the most critical period without competition between rice plants and weeds is about 20 days after transplanting, depending upon the kinds and density of weeds. Afterwards, as rice plants and weeds grew, the competition between them gradually became greater.

(2) The competition for light:

The extent of competition for light between rice plants and weeds was dependent upon the growth rate at the early stage, and on the form and height of the weeds.

Monochoria vaginalis and toothcup *(Rotala indica)* are short plants. Barnyardgrass *(Echinochloa cus-galli)* is as tall as the rice plant. A sedge which is called Tamagayatsuri *(Cyperus difformis)* in Japan, is between these two groups. In speed of growth, Monochoria is the fastest followed by sedge and barnyardgrass, respectively.

These differences in the height and growth rate of weeds had a great influence in competition for light as shown in Fig. 1. As Monochoria and toothcup were never taller than the rice plants throughout all stages of growth there was little competition for light in the weedy plot A in which the weeds were mainly these short weeds. At 40 days after transplanting, at the end of July, the intensity of illumination in the middle layer in the weedy plot A was about 50% of the open air, almost the same as in the no-weed check. Moreover, the ratio of weight between the rice plant and the weeds in plot A was the same at the beginning of August and at the end of July.

On the other hand, the case of the weedy plot B consisting mainly of barnyardgrass, however, there was serious competition for light. The height of barnyardgrass which had emerged just after transplanting caught up with the height of rice plants at about 20–40 days after emergence, and overtook the rice at the maturing stage. As a result, in this community, the intensity of illumination of the middle layer was 25% of the open air, half as much as the no-weed check. In addition, as the barnyardgrass has a fast rate of growth even in the later growth stage, the ratio of rice plants in total community weight in the plot B was clearly less at the end of August than at the beginning of July.

To summarize, in the case of the short weeds such as Monochoria and toothcup, the competition for light was negligible, while in the tall weeds like barnyardgrass it was serious, especially in the late stage of growth.

(3) Competition for nitrogen nutrition:

The extent of competition for nutrition between rice plants and weeds was determined by the amount of nitrogen absorbed by weeds and the root distribution of weeds.

Fig. 2 shows the periodical changes of nitrogen concentration in typical lowland weeds and rice plants grown in the fields. The nitrogen concentration in barnyardgrass was relatively low, almost the same level as rice plants. Monochoria and toothcup, however, showed a high content of nitrogen, about twice as much as the rice plants. Then, the influence of weeds on the weight of rice plants per unit weight of dry matter of weeds was greater in the case of Monochoria than that of barnyardgrass. This fact indicated that the competition for nitrogen-nutrition per unit weight in Monochoria and toothcup, which had high nitrogen contents, was greater than in barnyardgrass.

However, the amount of growth per individual of barnyardgrass at maturing stage was about 60-80 times as much as Monochoria and toothcup. Accordingly, the competition for nitrogen per individual of barnyardgrass was by far greater than Monochoria and toothcup.

Table 1 shows the contents of ammonium nitrogen in soil. This experiment is the same as shown in Fig. 1. The amount of ammonium nitrogen in the soil of the weedy plot decreased remarkably. That is, in weedy plot A consisting mainly of Monochoria and toothcup, the roots of which are distributed in the upper layer of soil, there was little ammonium nitrogen in the upper layer of soil. On the other hand, in weedy plot B consisting mainly of barnyardgrass, the roots of which are distributed throughout the soil, there was little ammonium nitrogen in both the upper and lower layers of soil.

Since the roots of the rice plant are distributed in all layers of the soil, the competition between rice plants and barnyardgrass for nitrogen nutrition was much greater than in the case of rice and Monochoria or toothcup.

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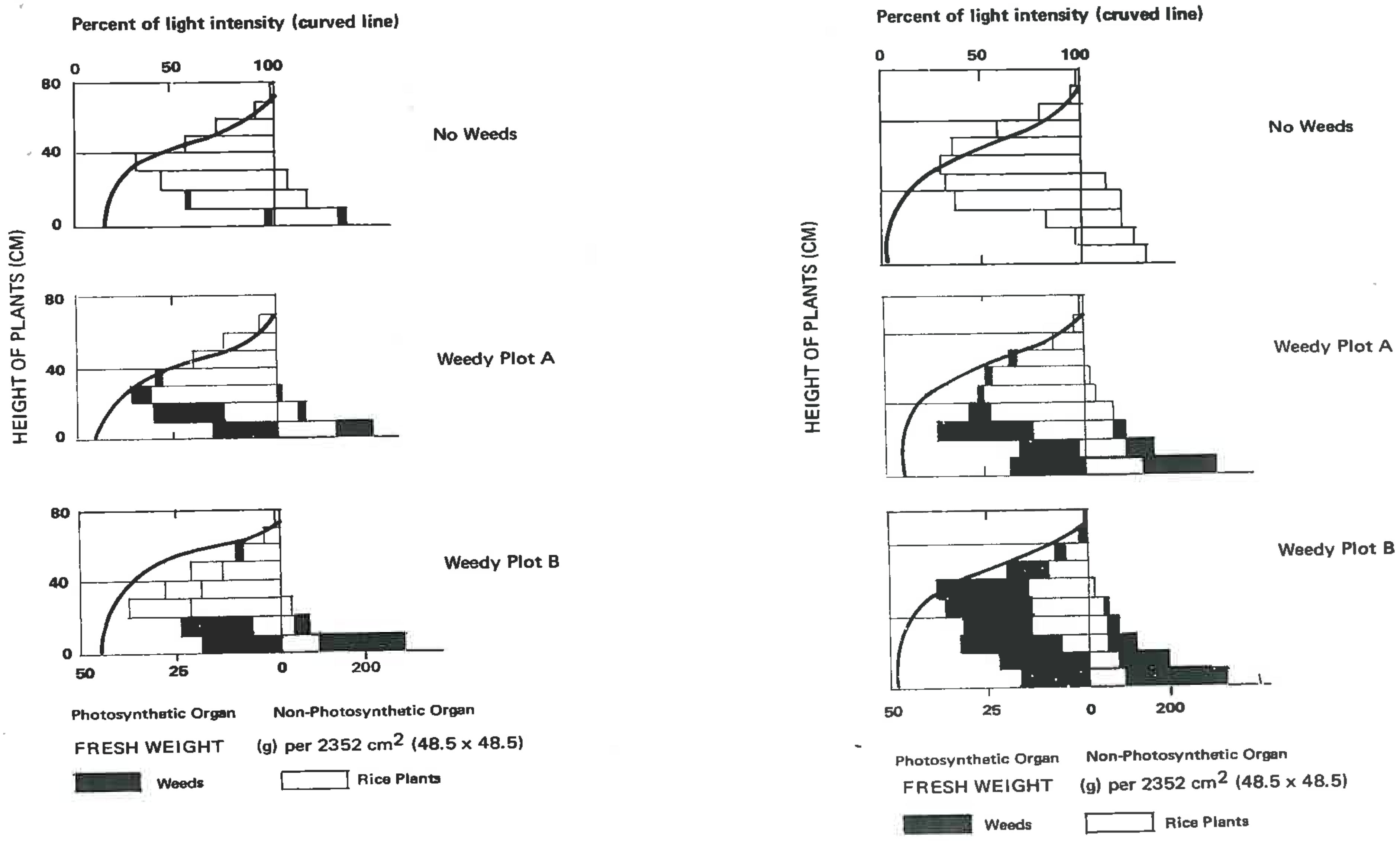

Fig. 1. Stratified structure of rice-weed community and penetration of light.

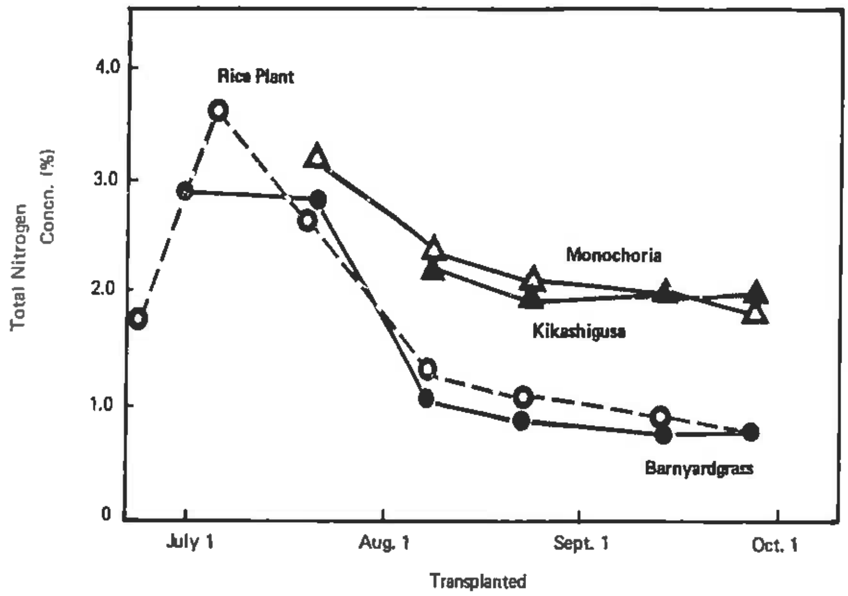

Fig. 2. Periodical changes of nitrogen concentration within plants.

As mentioned above, the extent of competition for nutrition was decided by the nutrient concentration of weeds, the growth of the individual weeds, the distribution of the root system and the periodical changes of these.

It may be generally concluded that the competition between rice plants and barnyardgrass, a large plant with a deep root system, is very great while the competition between rice plants and Monochoria or toothcup, which are small plants with a shallow root system, is not as great.

AN ANALYSIS OF THE DAMAGE TO RICE PLANTS BY WEEDS OF DIFFERENT COMMUNITIES IN TRANSPLANTED RICE CULTURE

(1) The relationship between kinds of weeds and the extent of damage on rice plants:

The decrease in yields of both rice plants and rice grains (per 100 g of dry matter of weeds at maturing stage) was almost the same among Monochoria, toothcup and sedge. In the case of barnyardgrass it was less than the former three weeds.

The rice grain yield was composed of the number of panicles and average weight per panicle. The decrease of rice grain yield by Monochoria, toothcup and sedge, was caused only by the reduction of number of panicles. However, in the case of barnyardgrass, the decrease in rice yield was caused by the reduction both in number of panicles and in average panicle weight.

Table 1. Contents of ammonium nitrogen in soil.

Dates	Plots	Ammonium Nitrogen (mg/dry soil 100g)		
		Upper Layer (0 - 5cm)	Lower Layer (5 - 10cm)	Average
July 18	No Weed	0.78	0.64	0.71
	Weedy A	0.26	0.36	0.31
(33)*	Weedy B	0.20	0.19	0.20
Aug. 3	No Weed	0.20	0.07	0.13
	Weedy A	0.15	0.00	0.07
(49)*	Weedy B	0.12	0.00	0.06

*days after transplanting

Table 2. Decreased percentage of the components contributing to grain yield by weeds.

Weeds	Grain Yield	Number of Panicles	Number of Spikelets per Panicle	Percentage of Ripened Grains	Weight of 1,000 Kernels
Monochoria	12.3	12.6	4.5	-4.4	-0.8
Barnyardgrass	10.0	7.4	1.5	1.2	-0.1

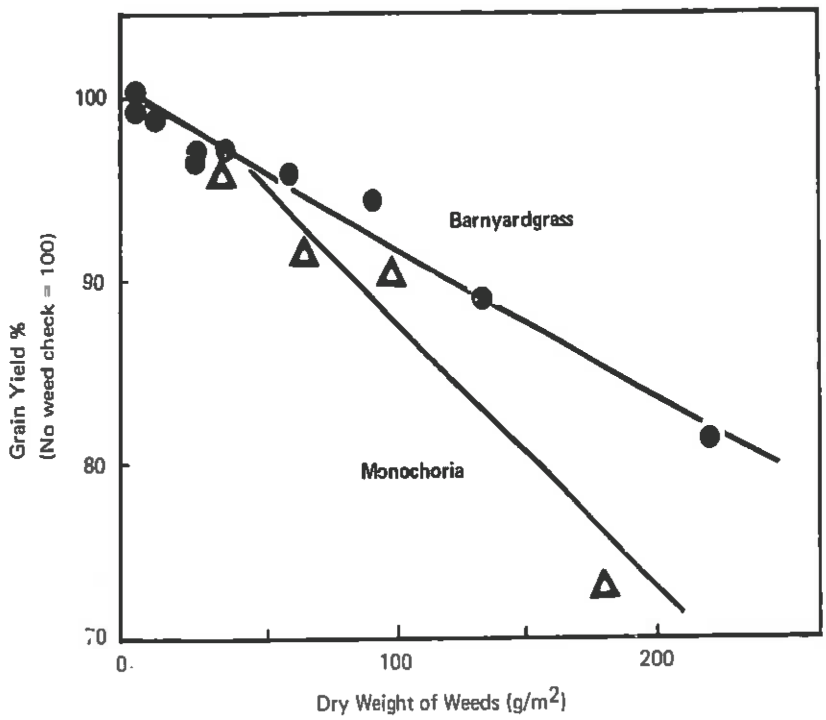

Fig. 3. Relationship between rice yield and weed weight at the matured stage.

From the difference of weed damage on the rice plant, weeds are divided into two groups; one is classed with barnyardgrass, the other consist of Monochoria, toothcup and sedge. As mentioned above, barnyardgrass has a marked effect on average weight per panicle. This may be caused by the severe competition for light and nutrients between rice plants and barnyardgrass even up to the ripening stage.

(2) Difference of damage on the components contributing to rice grain yield between barnyardgrass and Monochoria:

As mentioned above, barnyardgrass and Monochoria are very different in the mechanism of competition with rice plants. Table 2 shows the difference of the influence on the components contributing to rice grain yields. The grain yield was determined by the following four components: (1) the number of panicles per unit area, (2) the number of spiklets per panicles, (3) the percentage of ripened grains, and (4) the weight of 1,000 kernels. Though these components are associated with each other, they were determined in the following order: the first was the number of panicles determined on or about the 10th day after the maximum number of tillers stage; the second was the number of spikelets per panicle determined approximately the fifth day before the heading date; and the percentage of ripened grains was determined about 35 days after heading.

As shown in Table 2, the number of panicles was greatly decreased by weeds, but there was little influence on the weight of 1,000 kernels. Moreover, the number of spikelets per panicle was often decreased by Monochoria when the paddy field abounded with them, but in this case the number of ripened hulls was almost the same as the non-weeded plots because of the increase in the percentage of ripened grains, since the number of ripened hulls was the product of the number of spikelets per panicle and the percentage ripened. Furthermore, barnyardgrass influenced even the number of spikelets per panicle and the percentage of ripened grains, which were determined after the number of panicles.

As stated in the section on the mechanism of competition, these results were due to the difference of growth habit and mechanism of competition for light and nutrients among different weeds. In the case of Monochoria, the height of which was lower than rice and early growth of which was more rapid, competition for nutrients was more dominant than for light, especially in the early growth stage, so the number of panicles of rice determined at early growth stage was decreased. On the other hand, competition between barnyardgrass, which is as tall as the rice plant and which grows slowly, was greatest until the later growth stage of the rice plant. Consequently, there was an influence not only on the number of panicles but also on the number of spikelets per panicle and the percentage of ripened grains, which were determined at the later growth stage.

RELATIONSHIP BETWEEN THE YIELDS OF WEEDS AND RICE IN TRANSPLANTED CULTURE

As described above, the mechanism of competition with the rice plant is very different between barnyardgrass and Monochoria. Their effect on rice grain yield was found to be different from each other as follows:

(1) The decreased rate of rice grain yield per number of weed plants was higher in barnyardgrass than in Monochoria, because

barnyardgrass showed high competition for light and nutrients throughout the growth stage.

(2) When the density of weeds, barnyardgrass or Monochoria, became higher, the competition of that species became severe. In such cases, the decreased rate of rice grain yields per number of weeds became very low.

(3) The relationship between the weight of weed and the rice grain yield was linear at the matured stage. The rate of decrease of rice yield was somewhat larger in Monochoria than barnyardgrass. The high nitrogen content in Monochoria may be one of the reasons for this phenomenon (Fig. 3).

COMPARISON OF WEED DAMAGE BETWEEN DIRECT-SOWED AND TRANSPLANTED RICE CULTURE

Direct-sowing of rice plants resulted in weed emergence at almost the same time as the rice plants, hence their competition for nutrients and light was severe even at the early growth stage. Thus the decrease in rice grain yield per number of weeds was larger in the direct-sowed than in the transplanted method.

MODE OF ACTION OF HERBICIDES FOR RICE CULTURE

Shooichi Matsunaka[1]

In Japan, the use of herbicides has been increasing as shown in Fig. 1. After World War II, hormonal herbicides were introduced into Japan by the United States for broadleaf weed control in paddy fields. The amount of hormonal herbicides used increased gradually. In 1957, pentachlorophenol (PCP) was found to be useful for transplanted rice culture, and the area of PCP-sprayed paddy field increased tremendously. PCP has a high toxicity to fish, so troubles were encountered at the time of heavy rains. In the districts having a possibility of fish problems, new herbicides having low toxicity to fish are now being used.

In addition to PCP and hormonal herbicides, propanil, diphenylethers, dichlobenil or chlorothiamid, and s-triazines are being used for weed control in rice culture in Japan.

In this report, both the mode of action and the mechanism of selectivity of these herbicides will be discussed.

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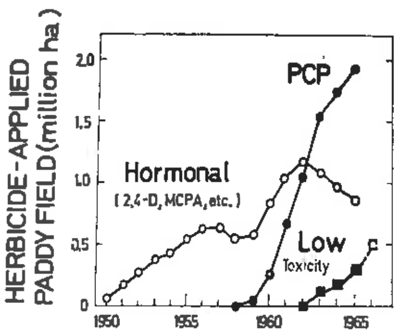


Fig. 1. Annual changes in area of herbicide-applied paddy field in Japan.

INHIBITION OF ENERGY FORMATION (PCP)

PCP inhibits the energy formation in aerobic organisms. The mechanism of biological energy formation in aerobic organisms consists of so-called electron transport systems and oxidative phosphorylation. Electrons delivered from the respiratory substrates such as malic acid, succinic acid, etc. will be transferred to oxygen and water level through these electron transport systems, coenzyme I, flavoprotein, ubiquinone and cytochromes. The difference in energy between respiratory substrates and oxygen during this electron trip will be converted into biological chemical energy, adenosine-triphosphate (ATP) through the mechanism of oxidative phosphorylation.

So-called uncouplers inhibit the formation of ATP in oxidative phosphorylation. Using the mitochondria from cauliflower, the author found that PCP decreased the P:O ratio in oxidative phosphorylation[1]. This means PCP may inhibit the oxidative phosphorylation even in higher plant mitochondria. PCP is one of the uncouplers as well as 2,4-dinitro-phenol, DNC, DNBP and others.

As a famous biochemical phenomenon, the velocity of respiration, O_2-uptake, is regulated by both the concentration of adenosinediphosphate (ADP) and inorganic phosphate (P_i). If ATP is used as an energy source for biosynthesis, protoplasmic movement, ion uptake, etc., ATP should be converted to ADP. Then the high concentration of ADP in cells will be a signal of the low level of ATP or biological energy. So, the phenomenon that the high concentration of ADP will accelerate respiration to increase ATP, seems to be very reasonable. Now if we put the uncouplers such as PCP into this regulation mechanism, they inhibit the formation of ATP, so the concentration of ADP will be high, and respiration will be accelerated. This relationship was found in the experiment using excised rice plant roots as shown in Fig. 2.[1)]

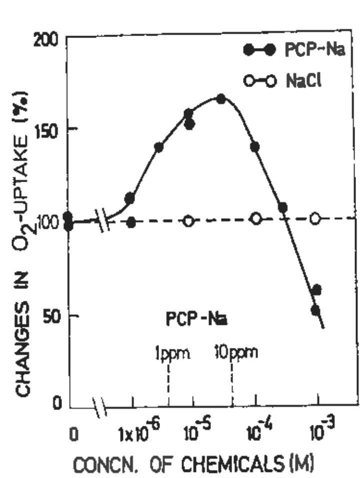


Fig. 2. Effect of PCP on O_2-uptake of rice roots (1).

The respiration of rice plant roots was accelerated 165% by the presence of PCP in 3 x 10^{-5}M. It should be noted that this concentration occurs in paddy fields.[1)]

PCP shows the inhibition of energy formation and acts on a number of aerobic organisms, not only weeds but also fish, snails, shell-fish or even microorganisms. However, PCP does not show any damage on transplanted rice plants. How is this discrepancy explained? The first factor is the granular form of this herbicide does not remain on the foliage of rice plants. Other important factors are the adsorption of PCP on soil particles and the safely located growing point of transplanted rice plants.

DISTURBANCE OF HORMONAL REGULATION (2,4-D or MCPA)

The second herbicide to be discussed is the hormone type. Five hormonal herbicides, 2,4-D, MCPA, MCPB, MCPP (mecoprop), and MCPCA are used in Japan. The fifth one, MCPCA (2-methyl-4-chlorophenoxyaceto-o-chloroanilide, trade name: mapica) was developed in Japan.

The mode of action of these hormonal herbicides depends upon the hormonal action, that is, the disturbance of normal hormonal regulation. However, even the final and primary mode of action of auxin itself is not yet known. Many biochemical and physiological changes by auxin have been reported.[2)] Among them, the effect of these plant hormones on DNA or RNA action seems to be the most important one from a standpoint of modern molecular biology.

On a technical base, the mechanism of the important selectivity of 2,4-D and others between monocotyledons and dicotyledons would be more important. As shown by Ashton[3)], the velocity of the translocation of 2,4-D is much faster in dicotyledons than in monocotyledons. This difference seems to be one of the mechanisms of the physiological selectivity as will be shown later and as presented by Osgood in this meeting.[4)]

INHIBITION OF PHOTOSYNTHESIS (PROMETRYNE)

When the primary action of a herbicide is the inhibition of photosynthesis of weeds, the following three conditions should be fulfilled:

1. Inhibition of CO_2-fixation or O_2-exhaustion.
2. Slow herbicidal activity, because the effect should be in carbohydrate starvation.
3. Recovery from the herbicidal symptoms by the artificial supply of sugars.

The herbicides having all of these conditions are s-triazines, phenylureas and substituted uracils. In this group, only prometryne, one of s-triazines, is used in rice culture in Japan. The mode of action of this herbicide is the inhibition of photosynthesis.

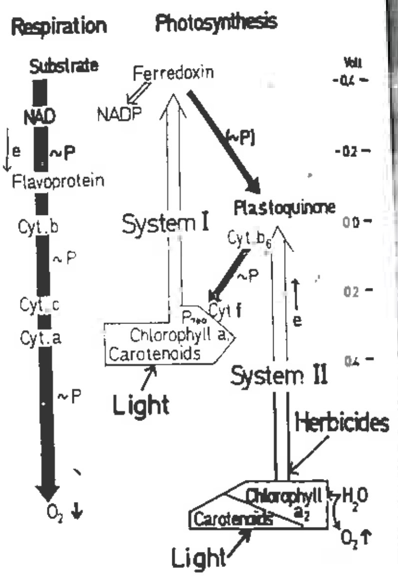


Fig. 4. Electron transport systems in respiration and photosynthesis.

In Fig. 4, the electron transport system in photosynthesis is shown. As mentioned above, in respiration the electron flow between the respiratory substrates and oxygen can yield the high energy source, ATP. In the case of photosynthesis, the solar light attacks the chloroplast pigments such as chlorophylls or carotenoids, and excites the electron to a high energy level. As the result of the down hill reaction of electron between plastquinone and chlorophyll a_2 or pigment-700, chloroplast can get ATP as an energy source and NADPH, the reduced form of coenzyme II as the reductive force. Both ATP and NADPH will be the necessary materials for the CO_2-fixation. The above-mentioned herbicides inhibit the lower part of system II of the electron transport system in photosynthesis. So the Hill reaction, O_2-exhaustion in the presence of some kinds of oxidants by illumination, is also inhibited by these herbicides.

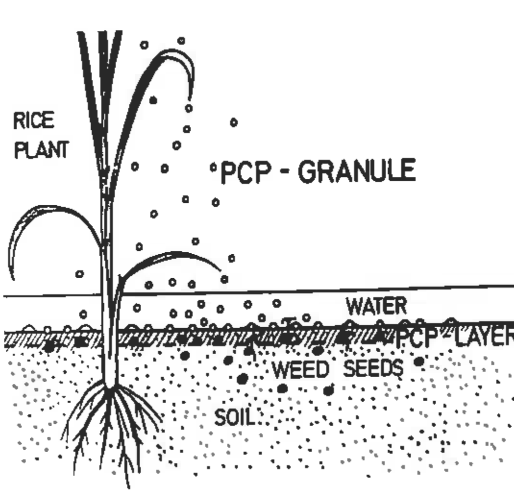


Fig. 3. PCP-granular herbicide in transplanted rice culture.

DRASTIC ACTION ON INTRACELLULAR COMPONENTS (PROPANIL)

Propanil can inhibit both the Hill reaction and photosynthesis, but we can not say that the mode of action of this herbicide is in the inhibition of photosynthesis, because the herbicidal symptom appears two days after the spraying. The real mode of action of propanil seems to be a more drastic one upon intracellular components although the fine mechanism is not clear yet.

On the other hand, the mechanism of selectivity of this miracle herbicide is clarified to some extent.

The mechanism of the selectivity has at least two factors; one is the susceptibility of intracellular components of barnyardgrass *(Echinochloa crus-galli* var. *oryzicola)* and other weeds. Intracellular components of rice plants are tolerant to propanil in this point. The other mechanism is the inactivation of propanil by the hydrolyzing enzyme of rice plants. As shown in Fig. 5, the recovery of the activities of photosynthesis and transpiration of rice plants were found in our laboratory.

The hydrolyzing enzyme has been studied to some extent by McRae[5], Adachi et al.[6], and Ishizuka et al.[7]. Adachi et al.[6] reported the distribution of this enzyme, which showed that the activity was high in rice plant and crabgrass *(Digitaria adscendens)* while in monochoria *(Monochoria vaginalis)* and barnyardgrass it was nil or very low.

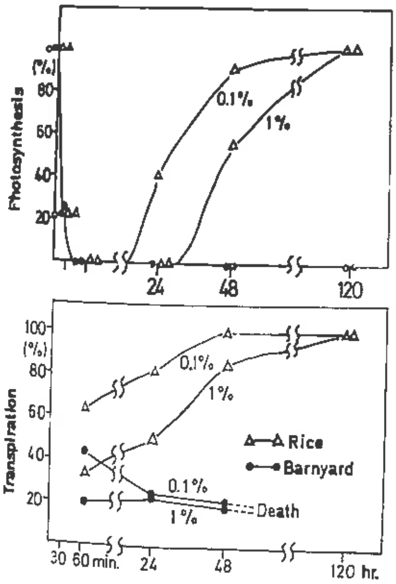


Fig. 5. Recovery of photosynthesis and transpiration in rice plants.

It is a well-known fact that some insecticides accelerate the damage on rice plants by propanil. This fact can be explained from the standpoint of enzyme chemistry. Adachi et al.[6] showed the inhibition of the inactivation of propanil by the enzyme in the presence of insecticides, carbaryl or dipterex.

As a result of these researches, one side of the mechanism of the selectivity of propanil may be illustrated as shown in Fig. 6. Propanil is inactivated by hydrolysis into 3,4-dichloroaniline and propionic acid. On the other hand, an insecticide, for example carbaryl, inhibits the inactivation of the enzyme which results in damage to the rice plants. However, this mechanism was utilized for crabgrass control in citrus orchard by WYDAC consisting of propanil and carbaryl as reported at another section in this meeting.[8]

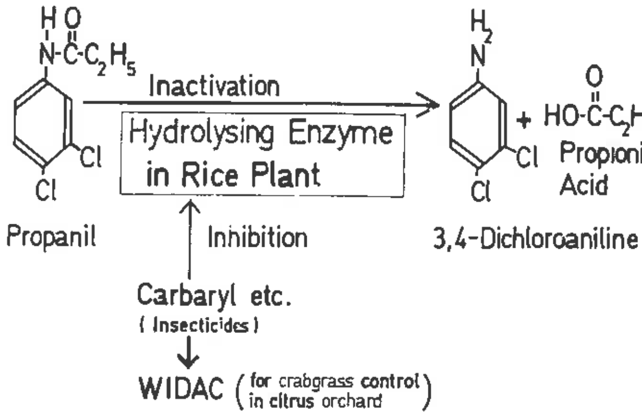


Fig. 6. Inactivation of propanil in higher plants.

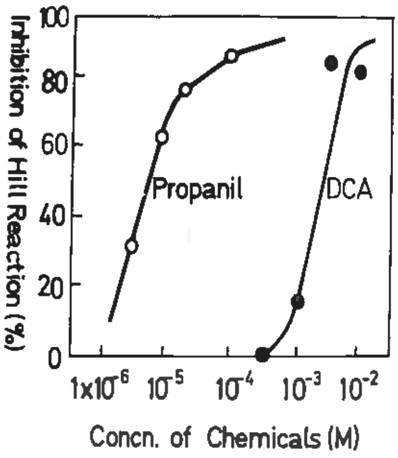


Fig. 7. Hill reaction.

The inactivated product, 3,4-dichloroaniline (DCA) has almost no herbicidal activity, and we found that 3,4-dichloroaniline has very low inhibitory activity on the Hill reaction as shown in Fig. 7.

Selectivity of herbicides would be classified into three groups, ecological (time lag or difference in location), physiological (difference in permeability and translocation), and biochemical (activation, inactivation and difference in attack sites) selectivities. PCP, 2,4-D and MCPA, and propanil are good examples of ecological, physiological and biochemical selectivities, respectively.

ACTIVATION BY LIGHT NIP (TOK) AND CNP

The last herbicide to be discussed is diphenylether compound as shown in Table 1. A number of diphenylether compounds has been tested for a long time in Japan. Now NIP (TOK) and CNP (MO) are being utilized for soil treatment in transplanted rice fields by farmers. Even in the diphenylether groups of compounds, HE-314 shows different properties as shown in table 1. These special properties themselves may be positively utilized for another purpose in rice culture.

NIP or CNP, and other diphenylether compounds having ortho position substitutions seem to be activated in the cells with light energy.

In Table 2, the oral toxicities of herbicides are shown. It shows that the mode of action has a very important relationship with the oral toxicities to rat. For the requirement of low toxicity herbicides, the former two groups, photosynthesis inhibitors and diphenylether compounds, may be recommended.

Table 1. Some properties of diphenyl ether herbicides.

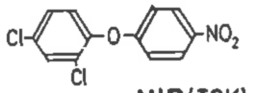
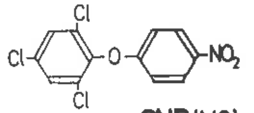
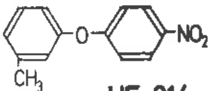
	Requirement for Light	Selectivity between Rice Plant & Barnyard-grass	Inhibition of Root Emergence
 NIP(TOK)	+	±	−
 CNP(MO)	+	±	−
 HE-314	−	++	+

Table 2. Oral toxicities of herbicides

Attack Point	Herbicides	Rat LD_{50} mg/kg wt.
	simazine	5,000
	prometryne	3,750
photo-synthesis	diuron	3,600
	bromacil	3,400
	(propanil)	1,384
activation by light	NIP (TOK)	3,580
	CNP (MO)	10,800
hormonal	2,4-D	500
	MCPA	700
	PCP	210
energy formation	DNC	26
	DNBP	40
	TPCL (organic tin)	109

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PRE-PLANT AND POST-EMERGENCE WEED CONTROL IN RICE WITH ORDRAM R [1]

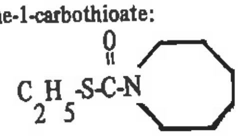
J. Antognini [2]

Ordram is a selective herbicide which has been used commercially for grass control under various rice growing cultures for the past 3 years. Ordram was tested under the code number R-4572 and the common name assigned to it by the Weed Society of America is molinate.

[1] Registered trademark, Stauffer Chemical Company

[2] Manager, Agricultural Field Research and Development, Stauffer Chemical Company, Mountain View, California.

Chemically it is S-Ethyl hexahydro-1-H - azepine-1-carbothioate:



The technical material is a liquid with a water solubility of 900 ppm, an acute oral LD_{50} to male albino rats of 720 mg/kg and an acute dermal LD_{50} to albino rabbits of greater than 10,000 mg/kg. The LC_{50} values on goldfish *(Cyrinus carpio)* and sunfish *(Leponis macrochirus)* following a 96 hour exposure are 30 ppm and 29 ppm respectively. The LC_{50} value for mallard ducks *(Anas platyrhynchos)* in a 5 day feeding study is greater than 13,000 ppm.

APPLICATION METHODS AND TIMING

Ordram can be applied in various ways depending upon the type of rice culture, timing of application, equipment available and formulation available. Applications can be safely made with either air or ground equipment. Ground applications can be made by hand, as well as with tractor equipment, or by broadcasting the granulars by hand as is commonly done in seeding grains. These methods of application apply to both the pre-plant and post-emergence methods of application discussed. In addition to safety to the applicator, Ordram is also safe to fish and wildlife. Seaman, et.al. (14) collected and analyzed water samples following pre-

Table 1. Water samples from fields treated with Ordram.

EXP. NO.	FORMULATION	ACRES TREATED		CONC. ppm* = INTERVALS AFTER APPLICATION 0	2½hrs.	5 hrs.	2 days
1	Liquid	18	Center of treated area	1.78	1.12	---	0.68
1	Granular	18	Center of treated area	0.96	1.29	---	0.73
1	Liquid & Granular	36	Spillway out of treated fields	---	---	---	0.74
2	Liquid	25	Center of treated area	1.64	---	2.39	0.68
2	Granular	50	Center of treated area	2.71	3.93	---	0.19
2	Liquid & Granular	75	3/10 mile downstream from spillway out of field.	---	---	---	0.22

*Ave. of 5 water samples.

plant applications of 3 lbs./acre of Ordram and found that initial effluent samples from three treated fields contained less than 0.4 ppm. In subsequent samples the concentration decreased rapidly with time and became undetectable (less than 5ppb) after 3 weeks of flow from each of the fields.

Data on water samples obtained by Orr and Senior (11) in California with post-emergence applications at 3 lbs./acre to the surface of flood water are presented in Table 1.

The differences in results between experiments can probably be accounted for by differences in size of fields, water depths and water flow rates between the two experimental areas.

With both the pre-plant and post-emergence applications, the concentrations of Ordram found in the fields and in the drain waters were well below levels found to be toxic to fish and wildlife.

Pre-Plant

Pre-plant soil incorporated and non-incorporated applications of liquid or granular formulations are effective on shallow seeded (¾" or less), water seeded and transplanted rice (1), (2), (3), (5), (6), (8), (9), (12), (13), (15), (16), (17).

If the soil is dry at time of application and no rainfall or heavy dews are expected between application and flooding, no soil incorporation is necessary Antonelli (2), Mueller (9) and Sarfaty (13).

If moisture is expected prior to flooding, soil incorporation by discing or harrowing must be carried out prior to occurrence of the moisture. If, however, the soil is moist at time of application, the Ordram must be incorporated into the soil immediately following application. In the case of ground equipment, this can best be accomplished by mounting the application equipment (liquid and granular) in front of the disc or harrow so that application and incorporation are done in one operation. If airplane application is used where soil incorporation is necessary the acreage treated per day should not exceed the area which can be covered by incorporation equipment the same day that application is made.

Following pre-plant applications the rice can be seeded or transplanted as soon as the field is in the proper condition for shallow drilling, water seeding or transplanting of the rice. Tolerance of rice to these applications is greater than 2 times the rate required for control of grasses.

Post-emergence

Application following the emergence of grasses has been successful with all types of rice culture involving deep drilled, shallow drilled, water seeded and transplanted rice (2), (3), (4), (5), (7), (8), (9), (13). Where rice is seeded it is approximately the same size as the grasses when application is made, but this is not necessary.

There have been reports (Sarfaty 13) that post-emergence Ordram applications to flooding have been successful. In general, however, this type of application has resulted in variable grass control. Uniformly excellent grass control has been obtained with applications made to the surface of flood water when watergrass size ranged from ½" to 10" high tillering (Smith 15). This has been confirmed by Stauffer Research and by commercial applications and Antonelli et.al. (2), Baker (3), Fischer, et.al. (5), Moomaw (7), Morse & Oelke (8), Sarfaty (13). Following post-emergence applications on top of the flood water it is important that the field remain flooded until after the watergrass dies which is 4-7 days for small grass and up to 3-4 weeks for large tillering grass. Therefore, there are three important reasons for making treatment when watergrass is small. First, if the field needs to be drained to apply fertilizer or to conserve water, it can be done in a shorter period following application. Along the small line, if the flood water is lost accidentally shortly following application, the control will be better when the grass is smaller at time of treatment. Second, the effect of competition on the rice is eliminated sooner than if large grass was treated. Third, in areas where water temperatures are very high such as in Mexico, submerging the rice for more than a few days will result in severe injury or death of the small rice seedlings. Another important factor to consider in regard to timing is that if both the rice and grasses are emerged from the mud, but not from the water, either the liquid or granular formulation can be used because application is made to a water surface. When application is made after the rice and grasses have emerged through the water, the granular formulation is more effective. This is due to the fact that the granular particles fall through the emerged leaves and settle into the mud where needed for weed control rather than being held on the leaves as would be the case with a spray application as shown in Table 2 by Dewald (4).

Table 2 Texas Experiment 1966 (1, 2, 3).

		% Control	
Formulation	Ordram LBS./A	Early Application Watergrass 3-4" High	Late Application Watergrass 8-10" High
Liquid	3	99	50
Granular	3	99	85

[1]Type of Application – Post-flood post-emergence by airplane. Early and late application.
[2]Depth of Flood Water – 4 to 5"
[3]Watergrass Population – Heavy

Table 3 Fischer, Swain and Boerema (5)

Chemical	LBS./A	Method of Application	Yield LBS./A
Ordram	3	Post-emergence-Field not flooded*	7548
	3	Post-emergence-Field flooded**	7642
	6	Post-emergence-Field not flooded*	7638
	6	Post-emergence-Field flooded**	8031
Propanil	3	Post-emergence-Field not flooded*	8325
	4	Post-emergence-Field not flooded**	5967
	5	Post-emergence-Field not flooded**	6307
Untreated	0		1348

*3 weeks after seeding
**5 weeks after seeding

Table 4 Moomaw, Navaro and Tauro (7)

Chemicals	Kg/ha	Days After Planting	Mean Yield Kg/ha
propanil	3	20	4704
MCPA	1	25	2806
propanil + MCPA	3 + 1	20 (propanil–35 (MCPA)	4415
molinate (Ordram) + MCPA	5 + 1	3 (Ordram)–45 (MCPA)	4511
no weeding			1605

Table 5 Mueller and Oelke (9)

Chemical	LBS./A	Method of Application	Paddy Rice LBS./A
Ordram	2	pre-plant incorporated	3940
	3	pre-plant incorporated	4820
propanil	6	29 days after seeding	3100
	6	37 days after seeding	3500
	6	51 days after seeding	2960
control	0		1830

RATES OF APPLICATION

Pre-plant applications

The standard rate of application regardless of formulation is 3 lbs. per acre[2]. In situations where application conditions are good, a 2 lb. per acre rate is sufficient for control of the more susceptible grasses such as *Echinochloa spp.* and *Digitaria spp.* Under adverse application conditions a rate of 4 lb/acre may be required. In many cases where 2 or 3 lb/acre results in poor control it is due to an excessive depth of incorporation (deeper than 1 to 2").

Post-emergence applications

With post-emergence post-flood applications the rate required is 2 to 3 lb/acre depending upon the formulation and timing of application. The 2 lb/acre rate is used with either formulation if application is made 2 lb/acre rate is adequate with the granular formulation, but the 3 lb/acre rate is required with the liquid formulation. Under all conditions the 3 lb. rate is required for control of *Leptochloa spp.* and *Cyperus spp.*

WEEDS CONTROLLED

In both pre-plant and post-emergence applications the following weeds have been controlled:

- watergrass – *Echinochloa crusgalli*
- watergrass – *Panicum crusgalli*
- Brachiaria – *Brachiara platyphylla*
- sprangletop – *Leptochloa panicoides*
- crabgrass – *Digitaria spp.*
- Umbrella sedge – *Cyperus spp.*
- hoorahgrass – *Fimbristylis miliacea*

YIELD DATA

Representative yield data obtained by various research workers are presented in Tables 3 to 8.

MATURITY

Dewald (4) has found in commercial size experiments that Ordram applied post-emergence on the flood water resulted in rice maturity 7 to 10 days ahead of recommended propanil applications. Yields for the experiments with each chemical applied at 3 lb./acre are contained in Table 9. The data show that yield was not sacrificed for earlier maturity.

[2]All rates in this paper are given in terms of lbs. of active ingredient.

Table 6 Mueller and Oelke (10)

Year	Chemical	LBS./A	Method of Application	Paddy Rice LBS./A
1962	Ordram	3	pre-plant	4600
		6	pre-plant	4670
		0		4120
1963	Ordram	1	pre-plant	3160
		3	pre-plant	3470
		5	pre-plant	3350
		0		2540

Table 7 Sarfaty (13)

Chemical	LBS./A	Method of Application	LBS./A
Ordram	2	post-emergence on top of 2nd irrig.	3610
	4	post-emergence on top of 2nd irrig.	5870
	6	post-emergence on top of 2nd irrig.	5776
control	0		1514
Ordram	3	post-emergence on dry bay ahead of flooding	6605
	4	post-emergence on dry bay ahead of flooding	4526
propanil	3	post-emergence on dry bay ahead of flooding	2603
	5	post-emergence on dry bay ahead of flooding	3360
Control	–		1894

Table 8 Velmorugu (17)

Chemical	LBS./A	Method of Application	Paddy Rice LBS./A
Ordram	0 (unweeded)		5216
	1	pre-plant incorporated	7336
	2	pre-plant incorporated	7736
	0 (unweeded)		5536
	1	pre-plant not incorporated	7568
	2	pre-plant not incorporated	5536
	0 (clean weeded)		6800

Table 9 Yield – Barrels Per Acre

CHEMICAL	EXP. NO. 1	EXP. NO. 2	EXP. NO. 3	EXP. NO. 4
Ordram	43.8	32	30	37
propanil	33.6	26	26	24

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DEVELOPMENT IN THE USE OF GRANULES AND MIXTURES OF HERBICIDES FOR RICE CULTURE IN JAPAN

Kenji Noda[1]

Weed control has been the most laborious but indispensable operation for sound crop production. It has been said in Japan that the proper cultivation of a crop should begin with a fight against weeds on the arable land. However, in recent years, the weed control program has been conspicuously changed with the introduction of chemical control methods which saved a great amount of labor. In Japan, this change was outstanding in weed control for paddy rice production. Tables 1 and 2 indicate the number of farmers using herbicides and the acreage and percent of fields in which herbicides were applied. According to these statistics, it is clear that herbicide use for paddy rice production is the largest.

We can usually classify rice culture in Japan into three types: transplanted, dry seeded and water seeded rice. Table 3 indicates the estimated acreage and percent of every cultural method or season. The transplanted culture in ordinary season is absolutely superior, amounting to as much as 92 percent of the total acreage. Thus, I will concentrate my attention on paddy transplanted rice culture in Japan and proceed with this paper.

GENERAL ASPECTS OF RICE CULTURE AND WEED CONTROL

Japan stretches along a south-north direction, and rice cultivation procedures and seasons therefore differ considerably by regions from south to north. However, it is assumed that the essential growing pattern of rice plants is basically alike throughout all of Japan. I will cite an example of the rice growing pattern from the warmer region of Japan. As shown in Fig. 1, the life history generally consists of four stages; nursery, tillering, panicle formation, and final ripening. Weed control operations must, by all means, be done by the end of the tillering stage, since the damage to rice plants by competition with weeds is most severe at this time.

Weed control programs for paddy rice production in Japan could be distinguished as three types until now, as shown in Fig. 1.

Before the introduction of foliage-applied herbicides like 2,4-D, the following operations made up a typical weed control program: thorough soil preparation before transplanting of rice seedling, precise water flooding to 3–5 cm depth, hand weeding soon after transplanting, two or three mechanical weedings, and one or two hand weedings of barnyardgrass.

After about 1950, as foliage-applied herbicides such as 2,4-D, MCPA, and MCPB were introduced, the mechanical weeding operation at about the end of the tillering stage came to be replaced by herbicide application.

Furthermore, the development of PCP as a soil-applied herbicide in 1959 eliminated not only mechanical weeding but also hand weeding just after transplanting, by which the labor requirement for weed control was reduced by about 50 percent. This introduction of a soil-applied herbicide has produced a revolutionary change in the weed control program for paddy rice production in Japan.

Thus the application of herbicides has been expanding more rapidly in paddy

Table 1. Number of farmers using herbicides for crop production in Japan.[1]

Crops	Total No. of farmers	No. with herbicides use[1]	Per cent
Lowland rice	4935	3633	73.6
Upland rice	786	202	25.7
Wheat and barley	3345	500	15.0
Potato	4503	34	0.8
Vegetables	5234	142	2.7
Fruits	927	43	4.7
Mulberry and tea	785	60	7.6
Others	3816	180	4.7

[1]Unit thousand ha.; Data are from MAF Statistics, 1964.

Table 2. Estimated acreage and percent of crops fields with herbicides use in Japan.[1]

Crops	Total acreage	Acreage of use	Percent
Lowland rice Soil-applied	3123.0	1674.3	53.6
Foliage-applied	3123.0	629.0	20.1
Total	3123.0	2303.3	73.7
Upland rice	132.4	95.5*	72.1
Wheat and barley	960.8	188.4	19.6
Sweet Potato	256.9	10.8	4.2
Irish potato	212.5	0.5	0.2
Beans	419.3	20.7	4.9
Corn	30.1	0.8	2.7
Sugar cane	13.0	0.5	3.9
Rape	85.4	0.4	0.5
Peanut	66.5	8.9	13.4
Vegetables	627.9	30.0	4.8
Fruits	351.2	13.6	3.9
Mulberry and tea trees	212.3	5.7	2.7
Mat-rush	9.3	2.6	28.0

[1]Unit thousand ha., Star is total of soil and foliage applied fields. Data are from "Japan Association for the Advancement of Photo-regulators".

Table 3. Estimated acreage (1,000 ha) for lowland rice production in Japan, 1964.

Culture methods		Acreage	Percent
Transplanted culture		3112.9	99.58
	Ordinary season	2884.5	92.27
	Early season	228.4	7.31
Direct seeded culture		13.1	0.42
	Dry seeded	8.3	0.27
	Water seeded	4.8	0.15
Total		3126.0	100.00

[1]Chief, Weed Control Laboratory, Kyushu Agricultural Experiment Station, MAF, Japan.

rice fields than in other crop fields. I would like to cite several factors contributing to this expansion.

1. Herbicide applications are especially effective and stable on paddy fields in combination with cultural methods such as soil preparation and water flooding.
2. In Japan, rice raising is generally more highly evaluated than other main crops, so that the investment of money for rice production is readily accepted.
3. The weeding operation in rice fields in summer is so hard that the rice growers are very anxious to free themselves from this particular operation by the use of herbicides.
4. Sound rice production is becoming impossible without employing labor-saving methods, because of a serious lack of labor in agriculture.

On the other hand, in addition to the matters above, I would suggest that the cooperative development of the creation of granular formulation and the establishment of proper usage techniques applicable to paddy fields have contributed very much to the nation-wide practical application of herbicides. I would then like to explain some featured aspects of herbicide application practices for paddy rice production in Japan, taking as a focus the granular and mixed herbicides.

GRANULAR FORMULATIONS OF FOLIAGE-APPLIED HERBICIDES

In Japan, the practice of 2,4-D application as a foliage-applied herbicide at a middle stage of rice growing was started with sodium formulations followed by amine salts in 1950. Both herbicides were very effective against broadleaf weeds, but they had some faults, being somewhat inconvenient in spraying operations since they must be sprayed after complete drainage of water, and were likely to cause a slight phytotoxicity because of overhead application on rice and weed plants. Accordingly, in order to remove the former inconvenience, an ethylester type which could be applied in water was developed, and in order to avoid the latter fault, a granular formulation was created. The ethylester wettable and its granule for each of MCPA and MCPB were also made up for the same reason as in 2,4-D. Consequently, the use of these herbicides became very easy and contributed to labor-saving. Generally speaking, 2,4-D has been applied in the southern part of Japan, and MCPA and MCPB in the northern part or in the case of early season rice culture. Table 4 indicates the present status of the usage of phenoxy type herbicides as a foliage application. Fig. 2 shows a trend that indicates 2,4-D is more suitable in southern prefectures.

It is basically supposed that the killing ability of granules might be poor in comparison with wettable or amine liquid, because of lower contact activity against the plant body. However, as shown in Table 5, there should be no essential difference in actual fields between the control ability of 2,4-D granules on weeds immersed in water and of the wettable formulation sprayed after drainage. It was, furthermore, made clear that the control ability of granule is hardly associated with the degree of distribution uniformity, because this is due to a quality of granules to easily diffuse into water and act uniformly against the surface of plants. It is thus concluded that 2,4-D granules pose no problem for application by hand alone or by hand-operated applicator,

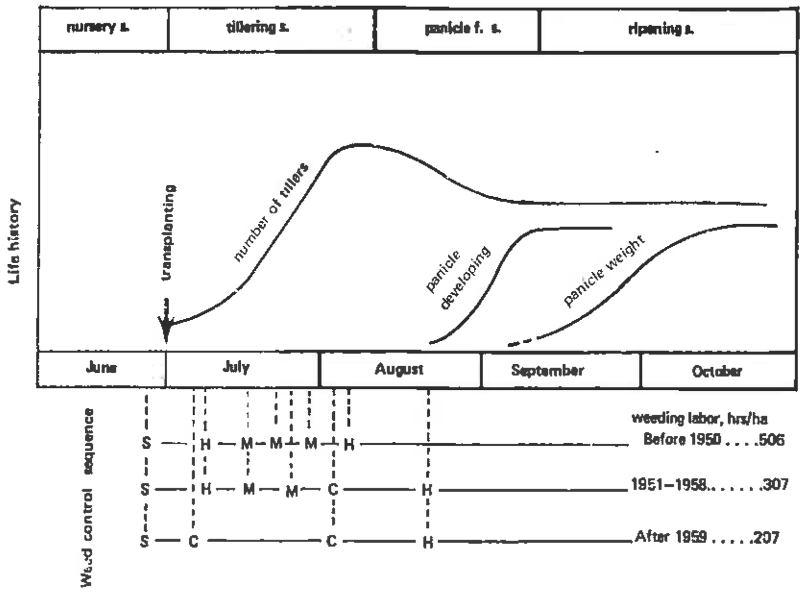

Fig. 1. Life history of rice and weed control sequence.

Table 4. Estimated acreage (1,000 ha) of the use of phenoxy herbicides in Japan, 1966.

Herbicides	Salt	Formulation	Acreage	Percent
2,4-D	Sodium	Wettable . . .	70	7.9
2,4-D	Dimethylamine	Liquid. . . .	176	19.8
2,4-D	Ethylester	Liquid. . . .	144	16.2
2,4-D	Ethylester	Granule . . .	186	20.9
MCPA	Sodium	Wettable . . .	43	4.8
MCPA	Ethylester	Liquid . . .	85	9.6
MCPA	Ethylester	Granule . . .	155	17.4
MCPB	Ethylester	Liquid . . .	0.4	0.0
MCPB	Ethylester	Granule . . .	30	3.4
(Total acreage used)			889.4	100.0

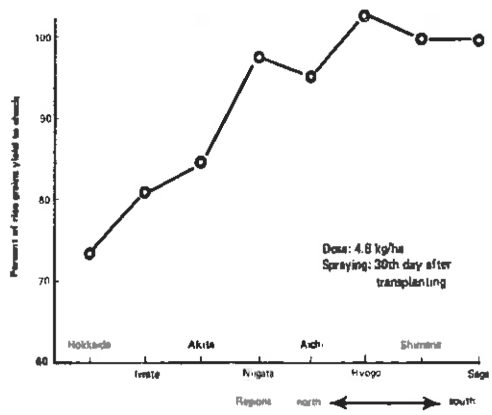

Fig. 2. Regional differences of phytotoxicity with 2,4-D on rice plants (joint study, 1949).

Table 5. Controlling effect of 2,4-D to broadleaf weeds (Arai and Miyahara, 1963)[1].

Plots	Formulation	Applied cond.	Number	Weight
Check			100	100
2,4-D-sodium	Wettable	Drainage . . .	1.9	1.0
2,4-D-ethylester	Liquid	Flooding . . .	18.2	6.5
2,4-D-ethylester	Granule	Flooding . . .	11.7	5.6

[1]Values are percent to check. Dose is 400g per ha as acid. Broad leaf weeds are *Monochoria vaginalis, Rotala indica, and Dopatrium junceum.*

Table 6. Acreage (1,000 ha.) of PCP usage for paddy rice production in Japan.

	1964		1966	
Total acreage	3156	100%	3129	100%
Acreage with PCP usage	1165	37	1224	39
with wettable	80	7	196	16
with granule	1085	93	1028	84

Table 7. Relationship between size of PCP granule and injury on rice plants (Arai and Miyahara, 1963).

Dose kg/ha	Range of grains diameter mm	Uniform application	Un-uniform application
7.5	0.50 – 0.75	0.4	1.7
	0.75 – 1.00	1.4	3.9
	1.00 – 1.25	3.6	9.4
	1.25 – 1.50	3.9	9.4
10.0	0.50 – 0.75	1.7	4.6
	0.75 – 1.00	3.2	7.0
	1.00 – 1.25	4.4	13.6
	1.25 – 1.50	8.3	20.9

[1]Values are percent of the sum of dead, and partially = dead plants to all used. Uniform and ununiform applications have 0 and 10%, and 20 and 30% in degree of increase or decrease of dose applied, respectively.

Table 8. Lesser toxic herbicides to fish and their estimated acreage (1,000 ha.) of use for paddy rice production in Japan in 1966.

Common name	Formulation	Chemical name	Acreage
MCPCA	Granule	2-methyl-4-chlorophenoxy aceto-o-chloroanilide	75
NIP	Granule	2,4-dichloro-4'-nitro diphenylether	122
CNP	Granule	2,4,6-trichloro-4'-nitro diphenylether	81
Prometryne	Granule	2-methylmercapto-4,6-bis (isopropylamino)-s-triazine . .	78
DBN	Wettable	2,6-dichlorobenzonitrile . . .	—
DBN	Granule	2,6-dichlorobenzonitrile . . .	16
DCBN	Wettable	2,6-dichlorothiobenzamide . .	—
DCBN	Granule	2,6-dichlorothiobenzamide . .	—

if the growing stage of weeds has not advanced above the water surface level.

GRANULAR FORMULATION OF PCP AS A SOIL-APPLIED HERBICIDE

PCP acts very effectively to kill weed seeds or juvenile weed seedlings and its practical application as a soil-applied herbicide got its start around 1959, by which a revolutionary change has been brought to the weed control program for paddy rice fields in Japan. However, PCP causes severe injury to rice seedlings when sprayed from overhead, because it has an acute action property. The development of the granular formulation was then strongly required in order to avoid this phytotoxicity.

As seen in Table 6, the use of PCP has spread most widely in paddy rice fields and now amounts to about 40 per cent of the total acreage. Among the PCP formulations, the granular form has a 90 per cent usage factor.

Although the PCP granule may not cause acute injury to rice seedlings, a slight chlorosis of leaves through the basal part of the leaf sheath, rarely resulting in complete death, is sometimes found. Such a phenomenon is likely to occur when applied under unfavorable environments such as high temperatures, excessive sunshine just after application, uneven granule distribution in unsound rice seedlings grown with too much nitrogen fertilizer, or under limited sunlight in the nursery.

Experiments have been conducted to study the phytotoxicity of PCP granules. The size of the granule, as seen in Table 7, has no influence on killing ability of weeds, but apparently does on the incidence of phytotoxicity to rice plants. The distribution of granules applied on the soil surface under water is also distinctly related to the occurrence of phytotoxicity. On the other hand, the quantity of carrier for creating granules is more or less related, but not to any great extent. Finally, I should conclude that an uniform application is most important in the case of PCP granules in order to avoid phytotoxicity, being different than the granules of foliage type herbicides such as 2,4-D and MCPA.

DEVELOPMENT OF LESSER TOXIC HERBICIDES

Since 1959, the use of PCP has been on the increase year after year, but a serious problem caused by its high animal toxicity occurred with respect to fisheries in 1962. That is, when heavy rains occurred right after application of PCP, this chemical flowed into rivers and seas in great quantities killing fish. From 1962 to 1963, the damage was serious in the warmer regions of Japan. Therefore, the development of new herbicides with less toxicity to fish and shell-fish was urgently required as a substitute for PCP granules.

As a result of extensive and cooperative studies throughout Japan, several useful herbicides, as indicated in Table 8, were developed. They are all granular formulations except for the wettable powder forms of DBN (dichlobenil) and DCBN (thiobenzamide). NIP (Tok), CNP, and prometryne act essentially on the shoot and leaf, consequently they are not available for overhead applications as emulsions or wettable formulations. On the other hand, NIP and CNP were highly evaluated for their low level of action by roots.

MCPCA, DBN, and DCBN showed little or no contact action; however they were formulated in granules for the purpose of facilitating the operation of application. As for DBN and DCBN, two formulations of wettable powder granules were developed, but they are not always similar in soil behavior so their effectiveness as an herbicide seems to differ to some extent.

Generally speaking, the herbicide from the granule moves in a greater quantity into the soil and has a longer residual activity. It is therefore more potent in its killing power as well as in its harmful effect on rice plants.

Table 9 indicates the action properties and soil behavior of main herbicides as PCP and lesser toxic herbicides. The total acreage of use for lesser toxic herbicides has increased very rapidly and amounted to about 370 thousand hectares in 1966, as seen in Table 8. Because the use of PCP in some areas is prohibited by the Kyushu prefectural government, less toxic herbicide use is estimated at about 80 per cent. Thus, at present the damage to fish and shell-fish from the use of PCP has declined greatly.

DEVELOPMENT OF HERBICIDE MIXTURES

PCP and lesser toxic herbicides are all very effective in controlling annual common weeds when properly applied, but are not always useful against all kinds of weeds or against older stages of weeds. For example, as soon as Fig. 3, PCP is ineffective on barnyardgrass *(Echinochloa Crusgalli* var. *Orizicola)* of over 1 leaf stage, or on all stages of slender spikerush *(Elocharis acicularis)*. NIP and CNP are also peculiarly ineffective against *Monochoria vaginalis* and slender spikerush. In order to eliminate such faults, mixtures of two or three herbicides having different properties should be utilized. Along such lines, several mixtures were created, as indicated in Table 10. Most of them are formulated in granules, and were developed as soil-applied herbicides to control not only annual weeds but also perennial weeds like slender spikerush in paddy rice fields.

However, one component of these mixtures, the phenoxy or nitril type herbicide, moves easily into the soil. It is therefore likely to cause injury to rice seedlings in comparison with an original single application of soil-applied herbicides such as PCP, NIP, and CNP. The use of these mixtures should be more or less limited to the areas of paddy fields where the leakage of irrigation water is less and perennial weeds like slender spikerush prevail. At present, PCP.MCP and PCP.MCPB have been used very much; they were developed earlier.

A mixture, ATA.2,4-D, was recently developed for the purpose of controlling slender spikerush by means of foliage application after harvesting rice plants. This mixture is more effective than single applications of ATA and 2,4-D; its action property seems to be somewhat synergistic.

Table 9. Soil behavior and action properties of several herbicides (Noda, 1962-65)[1].

Herbicides	Movement into soil ACL	HAS	Residue	Action by shoot	Response to high temp.
PCP	S	M	Short	Severe	Middle
MCPCA	M	G	Middle?	Small-No	Great-Middle
NIP	VS	S	Middle	Severe	Small
CNP	—	A	Middle	Severe	Small
Prometryne	S	S-M	Long	Middle	Great
DBN	S	G	Middle	No	Small-No
DCBN	G	G	Middle	No	Small-No

[1]S:small, M:middle, VS:very small, G:great.
ACL:alluvial clay loam, HAS: humic allophene soil.

Table 10. Mixtured herbicides registered and their estimated acreage (1,000 ha.) of use in 1966.

Common name	Formulation	Component	Acreage
PCP.MCP	Granule	PCP-Na+2-methyl-4-chlorophenoxy acetic acid allylester	467
PCP.MCPB	Granule	PCP-Na+4-(2-methyl-4-chlorophenoxy) butyric acid	58
PCP.MCPP	Granule	PCP-Na+2-(2-methyl-4-chlorophenoxy) propionic acid	6
NIP.MCP	Granule	NIP+2-methyl-4-chlorophenoxy acetic acid ethylester	—
CNP.MCP	Granule	CNP+2-methyl-4-chlorophenoxy acetic acid ethylester	9
PCP.DBN	Granule	PCP-Na+2,6-dichlorobenzonitrile	1
PCP.DCBN	Granule	PCP-Na+2,6-dichlorothiobenzamide	12
24D.ATA	Wettable	24D+3-amino-1,2,4-triazole	29
PCP.DBN.MCPB	Granule	PCP-Na+DBN+MCBP	9

Weeds \ Herbicides	PCP	MCP-CA	NIP	CNP	Pro-metr	DBN	DCBN
Echinochloa Crus-galli var. orizicola	○	△	■	■	■	△	△
Cyperus microirla, Fimbristylis littoralis	■	■	●	■	●	■	■
Rotala indica	●	●	●	●	●	○	■
Dopatrium Junceum	●	■	●	●	●	○	○
Monochoria vaginalis	●	■	■	■	■	○	○
Eleocharis achicularis	△	●	■	○	△	●	●

● Very Strong ■ Strong
○ Intermediate △ Weak

Fig. 3. Selective action of soil – applied herbicides to weeds (Kyushu Agr. Exp. Sta., 1962-66).

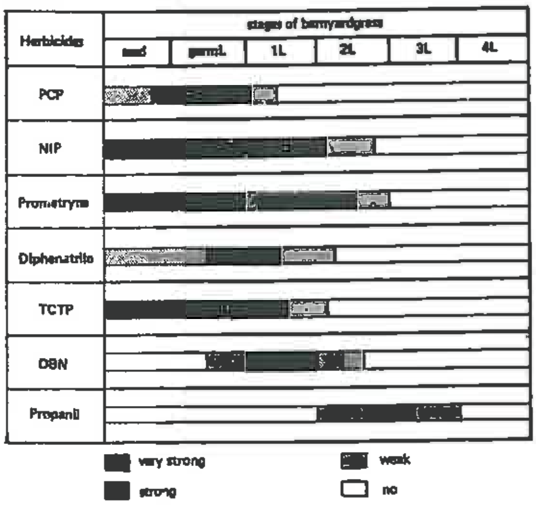

Fig. 4. Control spectrum for growing stages of barnyardgrass (Noda and Ozawa, 1964).

CONCLUSION AND FUTURE APPROACH

As described above, the practice of herbicide application for weed control in Japan has been pushed forward sometimes gradually and sometimes rapidly to the present time with the creation of granular and mixed herbicides and the development of their application techniques. However, the present know-how we have in Japan has by no means satisfied rice growers, and an urgent need for a better weed control program remains. I should like to present an approach to future programs of weed control in Japan.

1. The present soil-applied herbicides are generally effective against weeds only at certain limited stages; that is, they have a "narrow spectrum" for growing stages of weeds. Fig. 4 summarizes our experiment on control spectrum for growing stages of barnyardgrass. All herbicides were used, but propanil was found to be poor against more than the one-leaf stage. Rice growers are thus anxious to have better herbicides with broader spectrums.
2. As herbicides effective against only annual weeds have been used year after year, the infestation of perennial weeds has been gradually becoming serious. Therefore, new herbicides which are effective against both annual and perennial weeds and which cause no injury due to the long residual activity to rice plants are especially desired for future use.
3. At present in Japan, two applications of herbicides are customary in paddy rice fields, but a simple weed control program is required and should be valuable to save labor in rice production. For this reason, it is necessary to reduce the number of applications. In order effectively to control weeds with single applications of herbicides, it is necessary to develop herbicides with longer residual control but without phytotoxicity to rice due to the downward movement of the herbicides until late in the growing season.

MCPCA AND EARLY PADDY FIELD RICE HERBICIDE

K. Shigezane[1]

The history of paddy field herbicides in Japan originates in 1950 when 2, 4-D was first introduced followed shortly by MCP. Employment of 2, 4-D or MCP in sequence for many years in paddy fields 30 to 40 days after transplanting showed remarkable control of annual broadleaf weeds (such as *Monochoria vaginalis, Sagittaria pygmaea, Lindernia pyxidaria*, etc.). However, this caused a change in the weed community and promoted the predominance of *Echinochloa crusgalli* (barnyardgrass). Researchers of the Ministry of Agriculture and Forestry, universities, and private enterprises in Japan exerted their efforts to cope with the situation and completed a method of controlling barnyardgrass with PCP in 1957.

Because barnyardgrass is quite resistant to chemicals morphologically as well as histologically, high rates of chemicals have to be applied on this weed in its advanced stage, but this naturally also causes chemical damage to the rice plant.

Under the circumstances, in order to control barnyardgrass it is necessary to apply chemical control measures at the most susceptible stage of the grass, which is at seed germination. The chemical used for this purpose should have seed-killing activity as well as a short residual effect. Fortunately, PCP possesses these two properties. As a practical control method, PCP can be used pre-emergence to the grass before or after transplanting rice so as to kill barnyardgrass at its germinating stage.

In the event of PCP treatment before transplanting, the chemical will soon decompose and rice can then be planted. With post-transplant treatment, the possible chemical damage to rice plants was avoided by using granulated PCP. Through the introduction of PCP, weed control in paddy fields in Japan underwent a substantial change in that PCP was used pre-emergence in an early stage of rice cultivation while the usage of 2,4-D, 30 to 40 days after transplanting, declined to a great degree.

The practical usage of PCP in paddy fields proved that even an old chemical could be used successfully, depending upon the degree of research work done even amidst development of various new chemicals. Thus, the establishment of the weed control system wherein PCP was used in early stage of rice cultivation and phenoxy herbicides in latter stage contributed greatly to the chemical weeding of paddy fields in Japan (Fig. 1).

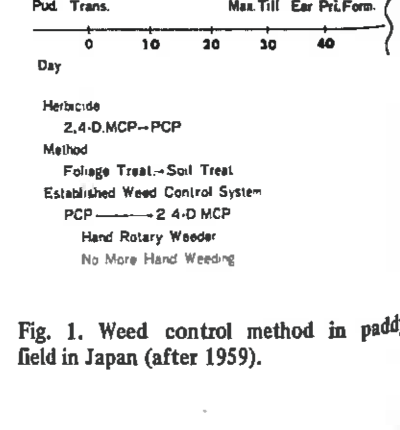

Fig. 1. Weed control method in paddy field in Japan (after 1959).

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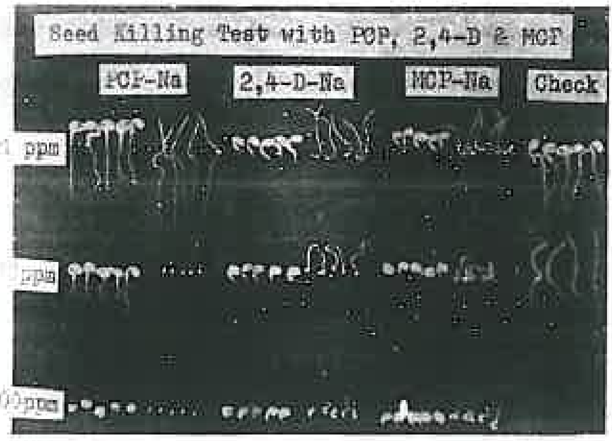

Fig. 2. Seedkilling test with PCP, 2,4-D and MCP.

However, PCP is not a super-chemical. It still has many disadvantages:

a. PCP is stimulative and tends to chap hands upon usage and will cause sneezing.
b. It has fish-toxicity.
c. It will not control *Eleocharis acicularis*, which is a second dominant weed in paddy fields.
d. In spite of a rather large quantity used, the residual effect does not last long and therefore treatment with PCP once during the season will not be sufficient for the purpose.

Under these circumstances, the technical staff of Ishihara Sangyo in an effort to solve these disadvantages of PCP, and to develop a second early stage paddy field herbicide, conducted research leading to the development of MAPICA granular (MCPCA).

DEVELOPMENT OF MAPICA GRANULAR

A necessary property which a pre-emergence herbicide should possess is seed-killing activity. In accordance with our "Examination method for seed-killing activity by different concentrations,"[1] PCP can completely kill germinating seed of barnyardgrass (a representative in graminaceous weeds) at 10 ppm and germinating seed of mung bean (a representative in broad-leaf plants) at 50 ppm. However, when 2,4-D or MCP were compared against these results, both 2,4-D and MCP showed the same results at as low a concentration as 1 ppm. Accordingly, it can be said that phenoxy herbicides are superior to PCP in seed-killing activity (Fig. 2).

[1]An examination method developed by Ishihara Sangyo in which germinating seeds of barnyardgrass (a representative in graminaceous weeds) and mung bean (a representative in broad-leaf plants) are treated with different concentrations of a test chemical in order to determine activities of the chemical through the observation of germination and rooting of the test plants.

Various properties of phenoxy herbicides can be enumerated as follows:

a. Seed-killing activity. (used pre-emergence)	High
b. Effect when used as a foliage treatment	High
c. Residual effect	Long
d. Leaching	Large

As explained above, phenoxy herbicides when used pre-emergence in the early stage of rice cultivation would produce better control effects than PCP on weed seeds at their germinating stage. However, due to the properties mentioned in (b) and (d), it is very clear that phenoxy herbicides would affect rice plants through both leaves/stems and roots and, further, due to the long residual effect as evidenced in (c), would certainly cause damage to rice plants for a long period.

Through these observations, our technical staff thought it would be possible that phenoxy herbicides could be used successfully as an early stage herbicide in paddy fields if we could maintain their seed-killing activity and long residual effect and, on the other hand, preclude or minimize their phytotoxic property through leaves/stems which constitutes a bottle neck in the case of an early stage usage, and also their inherent leaching property. Accordingly, we launched forth on research under a theme of "Research for the usage of phenoxy herbicides in an early stage of rice cultivation."

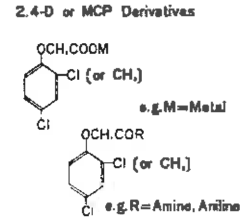

Fig. 3. 2,4-D or MCP derivatives.

Many a research report is submitted in which structure of molecules would be attributable to the activity of phenoxy herbicides. However, inasmuch as practical formulations are of salts, esters, amides etc., as shown in Fig. 3, we changed M and R into several forms so as to synthesize several derivatives and study their leaching property and phytotoxic property when they were used on leaves and stems.

As to M, re-evaluation was made on metallic salts such as Na, Fe, Al, studied previously during our research process of Aqua 2,4-D, a development of our own, and at the same time R was examined in the forms of amide, anilide etc. These examinations revealed that metallic salts, contrary to our expectations, did not exhibit any decrease in leaching property but amides and anilides compared with Na and ester showed very little leaching (Fig. 4).

In view of the test results obtained, M was abandoned and the study was centered on R. More than 10 formulations of amides and anilides were synthesized and tested as pre-emergence herbicides on simulated paddy fields at their early stage in pots (1/5,000 are)[2]. Having confirmed that amides and anilides are effective when used pre-emergence in irrigated paddy fields, we synthesized several hundred substituted amides

[2]1 are = 0.01 hectare.

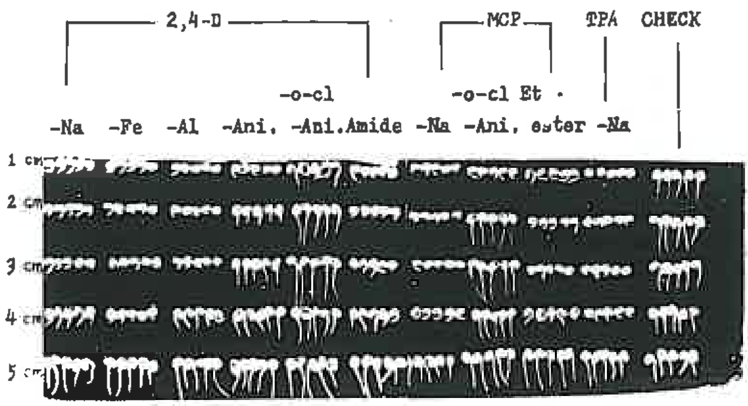

Fig. 4. Leaching in soil.

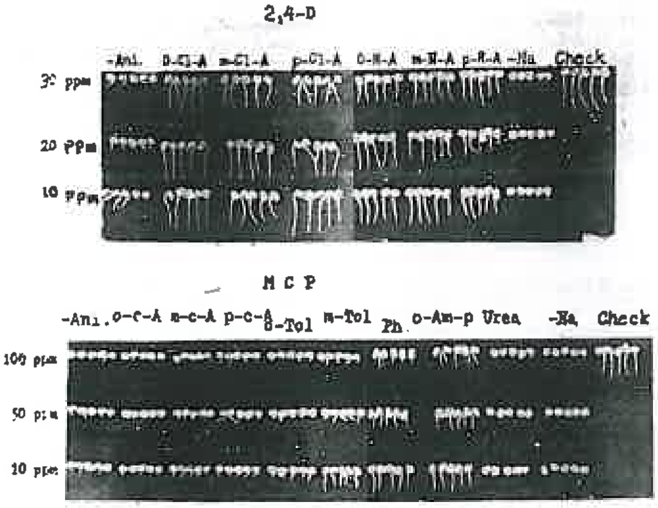

Fig. 5. Seed killing test.

Table 1. Seedkilling activity with 2,4-D derivatives.

Derivatives	M.P.	Activity 1ppm	10ppm	100ppm
(2,4-Dichlorophenoxy acetyl)				
-aniline	111-112	1	1	2
-o-carboxyaniline	221-222	1	2	3
-o-chloroaniline	125-126	1	2	3
-m-chloroaniline	130-133	1	1	2
-p-chloroaniline	162-164	1	1	2
-3,4-dichloroaniline	170-173	1	1	1
-2,5-dichloroaniline	182-184	1	1	1
-2,4,5-trichloroaniline	218-220	1	1	1
-o-toluidine	140-142	1	1	2
-m-toluidine	117-119	1	1	2
-p-toluidine	149-152	1	2	3
-o-nitroaniline	170-173	1	1	–
-m-nitroaniline	210-213	1	1	–
-p-nitroaniline	196-200	–	2	–
-urea	188-190	2	3	3
-triethanolamine	123-124	1	1	3
-d-naphthylamine	163-165	1	1	1
-b-naphthylamine	165-170	1	1	1
-o-aminophenol	232-233	1	1	–
-m-aminophenol	190-192	–	2	–
2,4-D	139-140	2	3	3

* 1···· Non-active
2···· 50% inhibition
3···· 100% inhibition

Table 2. Seedkilling activity with MCP derivatives.

Derivatives	M.P.	Activity 1ppm	10ppm	100ppm
(2-Methyl-4-chlorophenoxy acetyl)[redacted]				
-aniline	131-132	3	3	3
-o-chloroaniline	114-115	3	3	3
-m-chloroaniline	108-110	3	3	3
-p-chloroaniline	140-143	3	3	3
-o-toluidine	128-130	2	3	3
-p-toluidine	134-136	3	3	3
-2,5-dichloroaniline	170-172	1	1	1
-2,4,5-trichloroaniline	205-206	1	1	1
-o-nitroaniline	176-178	1	1	1
-m-nitroaniline	175-178	1	2	3
-p-nitroaniline	195-200	1	1	2
-o-aminophenol	120-123	1	1	2
-m-aminophenol	174-175	3	3	3
-urea	208-210	2	3	3
MCP - Na	118-119	3	3	3

* 1···· Non-active
2···· 50% inhibition
3····100% inhibition

and anilides of halogenated allyloxy carboxylic acid and these were subjected to screening tests.

Seed-killing tests were conducted with many synthesized compounds (see Fig. 5 and Tables 1 and 2). Through these tests we learned that 2,4-D derivatives upon amidification tend to decrease their seed-killing activity whilst a majority of MCP derivatives exhibited very little decrease in the activity. Further, both of the derivatives clearly exhibited a decrease in seed-killing activity when R substituent counted more than 2.

The results of foliage treatment tests obtained in pots (1/10,000 are) indicated MCPCA was less effective than the sodium salt of 2,4-D in foliage treatments (Fig. 6).

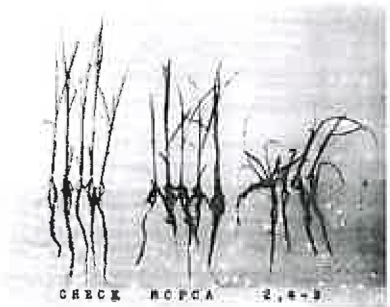

Fig. 6. Leaf treatment test with MCPCA

Wagner pots (1/5,000 are) were used for the tests in which 3 cm/8 hrs. water leaching was used. Soils of different layers were sampled and tested against barnyard grass. The results showed clearly that the leaching property of these compounds was decreased and that leaching of all substituted amides and anilides was less than half of the corresponding salts.

Pots (1/10,000 are) were used for residual effect tests. Soils sampled after a certain time were tested against mung bean. The results showed that residual effects of these compounds lasted equal or longer than corresponding salts. Some of the compounds appeared shorter in residual activity but this appeared to be so when their seed-killing activity was not large.

Through various tests such as seed-killing, foliage treatment, leaching and residual effect, the substituted amide and anilide compounds were determined as having practical value. Of all of these, O-chloroanilide was decided as the most desired compound in the light of activity (especially seed-killing activity) and economics. Thus MCPCA was selected.

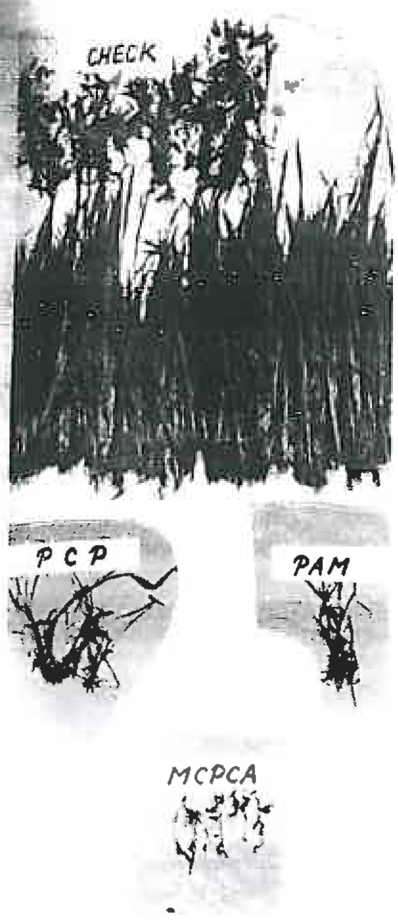

Fig. 7. Survived weeds in pot, 30 days after treatment.

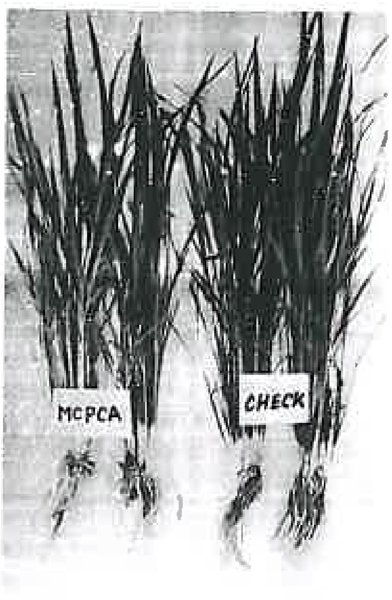

Fig. 8. Effect of MCPCA on rice plant.

The treatment of MCPCA in transplanted pady fields in concrete plots ($1^m \times 1^m$) resulted in excellent weed control and yet no damage on rice plants was observed (Fig. 7 and 8). In practical field tests, MCPCA also showed remarkable weed control.

As originally aimed, through decreasing the effect of foliage treatment and leaching, we were able to prevent MCPCA from attacking plants from both leaves and stems as well as roots, and further we were successful in maintaining a residual effect.

On the other hand, however, its seed-killing activity is somewhat weak. This can be overcome, however, by using higher concentrations in rather shallower treatment layers as compared with phenoxy herbicides (Fig. 9). The characteristics of MCPCA are described in Tables 3 and 4.

The practical methods of application in Japan are by hand, aerial and mechanical means. Application should be made as shown in Table 5.

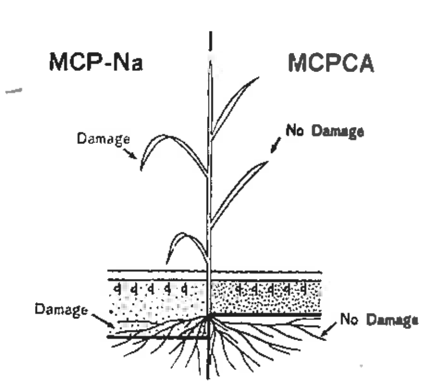

Fig. 9. MCPCA results compared to phenoxy herbicides.

Table 3. Characteristics of MCPCA Granular.

Physical and Chemical Properties

Appearance	whitish fine granular		
Active ingredient : 2-methyl-4-chlorophenoxyaceto-o-chloroanilide			2.5%
Inert ingredient		97.5%	
Characteristics of Active Ingredient			
Molecular wt.	310.2		
Melting point	112–113 C		
Solubility	Water : below 1ppm at 25 C		
	Organic solvent : easy		
Toxicity	Acute oral LD to mouse	2,560mg/Kg	
	Acute TLM to fish	1.7ppm	

Table 4. MCPCA herbicidal properties; weeds susceptible to MCPCA.

Herbicidal Properties

Persistence in soil	long
Leaching in soil	little
Time of application	Susceptible at germination stage of weeds
Absorption by foliage	very slow
Influence of temp.	More effective in warmer condition

Susceptible weeds

Echinochloa crusgalli (L.) Beauv.
Eleocharis acicularis Romer et Schultes
Cyperus difformis L.
Eichornia crassipes (Mart.) solms
Elatine triandra Schk.
Monochoria vaginalis Presl.

Table 5. Application of MCPCA.

Standard Method of Application

Rate per ha.	30 Kg granules
Time of application	Germinating stage of weeds (4 7 days after transplanting)
Soil	SL - C
Application	under flooded condition

SUMMARY

MCPCA was highlighted in 1963 as the first herbicide originally developed in Japan. It has low toxicity to fish. As an early stage paddy field herbicide, MAPICA is steadily gaining and contributing to the development of agriculture in Japan.

Being stimulated by the development of MAPICA granular, a domestic herbicide, other manufacturers in Japan are also coming up with their own products. This trend will certainly contribute to the advancement of Japanese agriculture.

PRE AND POST EMERGENCE WEED KILLERS FOR RICE

E. L. Chandler[1]

The use of broadleaf weed killers of the phenoxy type in rice continues in large volume in the United States and is expanding in usage in Central America. Not only are formulations improved, but better equipment now makes excellent weed control and safe weed control possible. A new development in 2,4-D has led to wide spread usage especially in areas where sensitive crops are grown near rice farms. This development, a formulation of Duomeen, allows phenoxies to be applied without fear of vapors emitting and causing damage to sensitive crops. While the major reason for formulating this oily type of amine was to prevent volatility, it soon became apparent that this specific material, N-Oleyl 1,3-proplenediamine salt of 2,4-Dichlorophenoxyacetic acid, had additional advantages on some very difficult-to-kill weeds. It is lipid soluble and very tenacious, which allows for excellent penetration and translocation in the weed plant without the tissue burning which is often obtained with esters. The standard water soluble amines do not give as much initial burn to the weed plant as do esters, but neither do they penetrate and give as good a kill on major deep rooted perennial weeds. The action of DACAMINE, which is the present registered trademark for this specific Duomeen, is usually much slower than that obtained with the ester forms of 2,4-D, but actually gives more total absorption and kill of perennial weeds.

There have been a number of other oil soluble amines tested by the Diamond Alkali Company and other American Companies, but most of them are of the primary amine type and these oily primary amines give inferior weed control compared to the Duomeens. The standard esters as well as MCP, are also being used widely in some parts of the United States and Central America where inter-cropping is not a problem. These materials are continuing to give good to excellent control of the standard annual and perennial broadleaf weeds.

The dimethyl ester of tetrachloroterephthalic acid (DACTHAL) was long ago found to be highly effective against many of the annual grasses and against some of the most important genera of weeds plaguing agriculture. Included in the highly sensitive weeds to Dacthal are: *Portulaca oleracea, Chenopodium album, Amaranthus spp. Euphorbia spp.* and *Richardia scabra.* Intermediate to good control has often been obtained on *Kochia spp. Polygonum Pennsylvanicum* and *Tribulus terrestris,* as well as certain solanaceaous species. Early work by Dr. Arai in Japan, and Dr. Moomaw of the International Rice Research Institute in the Philippines indicated that Dacthal might be an effective and safe weed killer for certain types of rice culture. Cultural practices and economics discouraged the development of Dacthal during its early inception, but improved economics should open the door for use in certain types of rice culture. There is a new interest developing and research workers are encouraged to re-evaluate DACTHAL at its lower cost. Intensive work has been started by workers in Central America and the results are outstanding. Even in countries such as Guatemala, Nicaragua, El Salvador and Costa Rica, with their difficult economic situations, Dacthal is now being used commercially and the large growers of rice are extremely pleased with their results. In these areas, rice is of the upland type and is not for the major part flood irrigated. Dacthal is used as a surface application at the rate of approximately 9 pounds of 75% active material per acre (approximately 10 kilograms/ha.). Most of the weed species in Central America are controlled by Dacthal because they are the type mentioned previously in this paper.

There is in Central America a considerable amount of propanil used and some of the large rice growers have switched from this material to DACTHAL. For the major part they have done this with their own research and development. The Diamond

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Alkali Company has consequently become very interested in the use of DACTHAL in transplanted rice and in all upland rice. We have received some reports of damage in seeded flooded rice in Arkansas, and more research is needed with this type of culture.

Regardless of the weed killer used, there is a great deal of interest developing in spray thickeners as an additive. These new materials not only reduce loss of spray due to drift, but stick the active ingredient on the treated plant and are giving increased efficacy. The Diamond Alkali spray gel material is called DACAGIN^R. This material is a dry granular botanical mixture and is sprinkled into the spray tank after filling with water. Approximately 4.6 pounds (2.8 kilograms) is added per 100 gallons of spray solution. The resultant mixture flows freely and pumps easily but is greatly thickened as it emerges from the spray nozzle orifice. The shearing action of the passage through the orifice increases, strangely enough, the viscosity of this solution. The resultant mixture is a flowable gel which can be sprayed from all conventional equipment. Fine screens and nozzles must not be used for the master screen and nozzles (screens should be 50 mesh or larger). This material is semi-commercial but research is continuing with it because of its added efficacy to pesticides, and to all types of weed killers, insecticides and crop defoliants.

It was discussed during this Conference that although economics are important, research workers should basically look at the merits of materials for what they can accomplish. If usage proves to be good and effective, greater chemical capacity can greatly reduce the cost of nearly any pesticide, DDT, which sold during its first few years at approximately six to eight times its current market price. This same phenomenon occurred with the phenoxy herbicides and will continue no doubt in the marketing of many of the new herbicides.

WEED CONTROL IN RICE

H. L. Vincent[1]

Rice is the major food crop of Asia. For centuries, rice has been grown in tropical Asia under conditions of minimum management. Attempts to keep production increasing at a rate equal to population growth have been mainly through increased planting areas and not through significant increases in yields per unit area. Examples of average yields (tons per hectare) for the period 1960-1962 are as follows: India–1.5, Pakistan–1.6, Burma–1.65, Thailand–1.4, Indonesia–1.9, and the Philippines–1.1. During the same time, the average yield in Japan was 4.8, United States–3.9, and Australia –6.3.

It was my pleasure to be closely associated with the rice industry from 1960 to 1966 in the United States specifically in the upper Mississippi Delta Region of Arkansas and Mississippi. During this period, area rice acreage increased from 384,000 to 477,000 acres and production increased from 4.4 to 5.5 tons per hectare, an increase of 25%. This increase in yield per unit area was achieved mainly through utilization of an effective herbicide program in combination with optimum fertilization.

The importance of weed control research in rice and subsequent utilization of this knowledge can be a major factor in improving living standards in all areas of the world. Despite the importance of weed control in rice, or any other field crop for that matter, yields are determined by a series of production factors and conditions. When these production factors are optimum, yields will be maximum. Dr. S.J. Wortman reviewed these factors at the Weed Society of America meeting in Washington D.C. on February 13-16, 1967, in a speech entitled, "The Crop Production Equation." In his talk, Dr. Wortman pointed out that production factors such as variety, fertilizer types and rates, soil conditions, water, spacing, climate, disease and insect control, and weed control must be optimum in order to attain maximum yields. If any of the factors are less than optimum, yield will be reduced – in fact, if any factor in the "equation" has a value of zero, the resulting yield may be zero. In your tropical areas where frost dates are not a problem as they are in the temperate zone, you may have to modify this formula to obtain maximum yield per day the crop is in the field rather than total yield per crop season, thus obtaining a higher total yield per year.

There was a natural tendency of nations with relatively high rice yields to offer assistance to lower producing nations with the obvious solutions – increase fertilization, initiate weed, pest and disease control programs. This was just not the case. For example, the rice variety Peta responds to nitrogen levels about 30 kg. per hectare with steadily declining unit yields (Fig. 1). The addition of other improvement practices with

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this widely accepted native variety was equally futile. Introduction of Japanese rice varieties when introduced into the tropics, did not have grain qualities acceptable to local tastes. In addition, lack of grain dormancy may cause the seeds to sprout in the panicle if there are rains at harvest. Similarly, the varieties developed in the United States did not adapt to tropical conditions except in areas where direct seeding was feasible. They did not prove suitable for transplanting, the normal planting practice in many tropical areas.

It becomes apparent then that we as weed workers, in order to develop a suitable rice herbicide, must be a part of the over-all rice improvement project in our area. We can often be influential in the direction of such a project. For instance, we may allow the breeders of upland varieties to utilize thick stands of an upright variety if we can assure him that economic weed control is available and will allow utilization of such a variety. In paddy areas, we may be able to allow the agronomist to utilize better fertilization and water management practices if we can show an economic method of weed control to substitute for cultural methods of controlling a grass species such as *Echinochloa crusgalli*. In areas where water seeding is practiced and varieties are adaptable to high water management, the development of selective herbicides to prevent aquatic weeds and algae gives the breeder maximum leeway in selecting varieties for specific needs.

The importance of weeds in reducing rice yields is startling. For example, working with Dr. R. J. Smith, USDA-Stuttgart, Arkansas, we determined that one barnyardgrass plant *(Echinochloa crusgalle)* per square foot reduced rice yields significantly enough to justify the application of an effective herbicide costing $15.00 per acre and still give the grower a good economic return on his investment based on United States rice prices in 1964. Prior to the introduction of selective grass herbicides suitable for rice, a grass infestation of one plant per square foot of area seemed insignificant to growers.

Another statement on the importance of weed control in upland rice is taken from the 1965 Annual Report (8, p 227) of the International Rice Research Institute located southwest of Manila.

> An important reason for low yields of most upland rice is the absence of effective, low cost weed control. A few varieties will produce yields nearly equal to those of flooded rice, but many of the short-statured or low-tillering types will be outgrown and over topped by weeds, especially under high fertility conditions. Hand weeding is effective and widely practiced but the cost of human labor is high and rice production returns are used effectively only in corase-textured soils and are seldom good enough to permit maximum yields. Effective chemical measures could greatly increase the returns to labor and management and entirely change the outlook for upland rice.

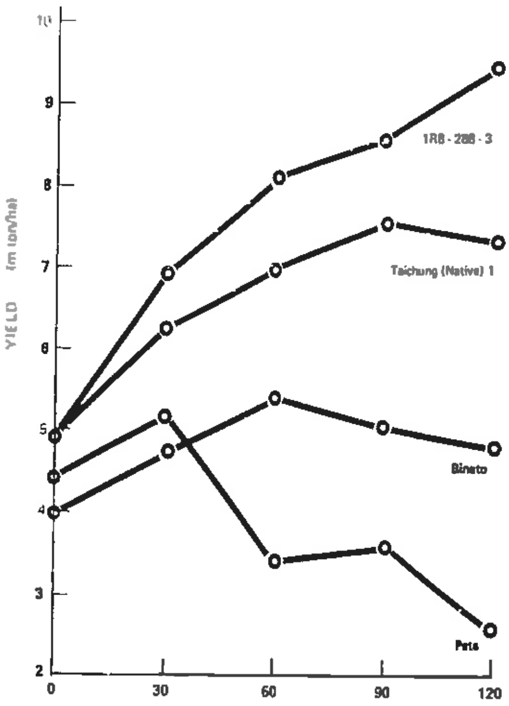

Fig. 1. Response to nitrogen of four rice varieties, 1966 dry season, International Rice Research Institute.

Results of a wet season weed control experiment given in the same annual report vividly illustrate the problem and the opportunities. Three herbicides were compared with no treatment at all. With no weeding of a drilled planting, the average yield was 515 kilograms of grain per hectare and with hand weeding, the yield was 3,943 kilograms per hectare. The three hand weedings required an average of 280 man-hours per hectare. With the use of one of the herbicides, the yield was 3,500 kilograms per hectare. The utility of herbicides in Asia or any other rice growing area will depend upon their effectiveness and safety and upon their cost relative to hand labor. The higher the yield potential the more likely it is that the economic control of weeds will be achieved through herbicides.

I consider herbicides a major tool in producing increased rice per unit of land in all areas. As a commercial agronomist employed by a major company doing herbicide research, every effort will be made to discover new selective herbicides capable of controlling economic weed species. We will make every effort to utilize the products of our research to improve the economic progress and human well being of people growing rice and utilizing rice as a major ingredient in their diet.

The real job in utilizing the product of government and private research lies in your resourcefulness as weed workers – in adapting new products and practices suitable for the rice industry in your area. An awareness of products and practices from all areas of the world is essential for the efficient performance of your work. An increasing awareness of improved application techniques makes available herbicides more effective. Improved cultural practices and utilization of improved plant characteristics are essential in reducing weed pests. Many effective herbicides are already available and the increasing emphasis on rice research makes our job a challenging one indeed.

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EVALUATION OF HERBICIDES FOR WEED CONTROL IN LOWLAND RICE

M. R. Vega, J. D. Ona and F. L. Punzalan[1]

This report describes results from the evaluation of Glenbar, TOK and Treflan for weed control in lowland rice. Four experiments conducted over a period of two years (1965 and 1966) are involved. A fifth experiment reports on a season's trial on the relative effectiveness of Ihara Chlos, Molinate, OCS-21799, TX-1120 and UC-22463. The chemical nature of the herbicides may be seen in Table 6.

MATERIALS AND METHODS

All experiments were conducted at the lowland rice fields of the University of the Philippines, College of Agriculture. The common sedges found in the experimental area were: *Cyperus iria, C. difformis, Fimbristylis miliacea* and *Scirpus mucronatus. Monochoria vaginalis, Jussiaea suffroticosa* and *Sphenoclea zeylanica* comprised the broadleaved species. The grass weeds were mainly *Leptochloa chinensis, Paspalum dilatatum* and *Echinochloa crusgalli.*

Land preparation consisted of one plowing followed by 2 or 3 harrowings; the latter operation utilized a "comb-harrow". "Dapog" rice seedlings were then transplanted (25 x 30 cm) in plots measuring 2 x 5 or 4 x 5 m. Plots were separated from one another by small dikes constructed around each plot.

For a dry season crop, transplanting is done in January or February, while a wet season crop commences in July or August. Harvesting is done in May or June and November or December for a dry and wet season crop, respectively.

RESULTS AND DISCUSSION

A summary of the results from an experiment carried out during the wet season of 1965 is presented in Table 1. The experiment consisted of separate trials evaluating different concentrations of Glenbar, TOK and Treflan applied at different dates after transplanting. Two concentrations (1 and 2 kg/Ha) and two dates of application (5 and 10 days after transplanting) were tried with Glenbar and Treflan. TOK was applied at 2 or 4 kg/Ha just before or 5 days after transplanting. The treatments presented in Table 1 are the better treatments found in the experiment.

The effectiveness of different concentrations of Glenbar, TOK and Treflan applied at different times was again tested during the dry season crop of 1966. Results are summarized in Table 2. An additional concentration (½ kg/Ha) for Glenbar and Treflan was included. For Glenbar and Treflan, a follow-up treatment of either ½ kg/Ha 2,4-D or one handweeding was made, while handweeding was the only subsequent treatment for TOK. These follow-up treatments were designed to control the weeds that survived the basic herbicide treatment. In the experiment the weeds started to germinate about 10 days after transplanting. The emergence of the grass weeds propagated from seeds was effectively prevented by 1 or 2 kg/Ha of either Glenbar or Treflan. The sedges and the broadleaved weeds were however not as susceptible to the above herbicide treatments. They were controlled by ½ kg/Ha of 2,4-D amine applied at 40 days after transplanting. Grasses from seeds, sedges and broadleaved weeds were susceptible to 2 to 4 kg/Ha TOK broadcast either at transplanting or 5 days after transplanting provided there was about 2 inches of water in the paddy. *Paspalum dilatatum*, a "creeper" propagated from stems and rhizomes, was very tolerant to all the herbicide treatments. The only effect noted on this species was slight stunting and a delay in their spread. Among the herbicides used only TOK caused phytotoxicity on rice plants. The portion of the older

Rice showing effect of weed control with propanil. Left, 6.72 kg per hectare of propanil gave complete control of *Echinochloa colonum.* Right, note heavy growth of grass weeds.

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leaves in contact with the "TOK-contaminated" irrigation on water rotted, causing collapse of these leaves. Injury to the rice plants was greater among the plants treated with 4 kg/Ha TOK at transplanting than among those treated 5 days after transplanting. TOK at 2 kg/Ha applied at planting was least injurious. Grain yields from the Glenbar-treated plots receiving the additional spray of 2,4-D were about twice that from unweeded plots. When the Glenbar plots were weeded instead of being sprayed with 2,4-D, grain yield was further increased. This latter observation is due to the presence of the resistant grass *P. dilatatum* in the experimental area. Even without any additional treatment TOK brought about increases in grain yield over the control. A far greater increase was however obtained when an additional weeding was done. Regardless of the additional treatment given Treflan brought about substantial increases in grain yield compared to the yield from unweeded plots. But as in the case of Glenbar and TOK increase in grain yield was greater among the Treflan plots given an additional weeding than among those sprayed with 2,4-D. Again

Table 1. Field evaluation of Glenbar, TOK and Treflan for weed control in lowland rice, wet season, 1965. Rice variety – BPI-76.

TREATMENT	Grain Yield (Kg/Ha)
GLENBAR	
1 kg/Ha at 10 days[1]	3345
2 kg/Ha at 10 days	4100
Handweeded Check	4006
Unweeded Check	2697
TOK	
2 kg/Ha just before planting	2254
4 kg/Ha just before planting	1978
4 kg/Ha at 5 days	2258
Handweeded Check	2155
Unweeded Check	911
TREFLAN	
1 kg/Ha at 10 days	4941
2 kg/Ha at 10 days	4696
Handweeded Check	4583
Unweeded Check	4362

[1] Days after transplanting.

Table 2. The effectiveness of Glenbar, TOK and Treflan for weed control in lowland rice, dry season, 1966.

TREATMENT: Main Herbicide Kg/Ha	Days	Additional	Dry weight of Weeds: 10 sq m. at 27 days	Dry weight of Weeds: 0.1 sq. at 71 days	Grain Yield (Kg/Ha
GLENBAR:					
1/2	10	1/2 kg 2,4-D		30	4540
1/2	10	1 weeding	585		4925
1	10	1/2 kg 2,4-D		30	4228
1	10	1 weeding	241		5721
2	10	1/2 kg 2,4-D		27	4130
2	10	1 weeding	224		5959
TOK:					
2	0	--		38	3655
2	0	1 weeding	316		5722
4	0	--		55	3220
4	0	1 weeding	256		5090
4	5	--		30	3184
4	5	1 weeding	193		5358
TREFLAN:					
1/2	10	1/2 kg 2,4-D		50	3873
1/2	10	1 weeding	467		5672
1	10	1/2 kg 2,4-D		43	4380
1	10	1 weeding	389		5672
2	10	1/2 kg 2,4-D		33	4808
2	10	1 weeding	106		5161
Handweeded	--	3 times			6114
Unweeded	--	--	1209	104	2450

$HDS_{.05} = 218$

Table 3. The relative effectiveness of applying Glenbar, TOK and Treflan either before or after a handweeding, wet season, 1966.

TREATMENT	Man-days to weed a hectare (8 hr/day)	Yield (Kg/Ha)
GLENBAR:		
2 kg/Ha at 10 days + 1/2 kg/Ha 2,4-D at 30 days	--	4287
2 kg/Ha at 10 days + 1 handweeding at 25 days	31.8	4740
Handweeding at 20 days + Glenbar, 2 kg/Ha at 30 days	24.2	4766
TOK:		
4 kg/Ha at 5 days + 1 handweeding at 25 days	21.1	4757
Handweeding at 20 days + TOK, 4 kg/Ha at 25 days	23.2	5202
TREFLAN:		
1 kg/Ha at 10 days + 1/2 kg/Ha 2,4-D at 30 days	--	4907
1 kg/Ha at 10 days + 1 handweeding at 25 days	16.9	4967
Handweeding at 20 days + Treflan, 1 kg/Ha at 30 days	20.3	4973
Handweeded, 3 times	--	4336
Unweeded	--	2876

HSD.05 = 1955

this observation is attributed to the presence of the tolerant grass weed *P. dilatatum*.

Two other experiments were conducted (wet season, 1966 and dry season, 1967) to further evaluate Glenbar, TOK and Treflan. Previous studies have shown that either a 2,4-D spray or a handweeding should follow a Glenbar or Treflan application. A 2,4-D spray is sufficient (where resistant grass species like *P. dilatatum* are absent) to control surviving sedges and *dicotyledonous* weeds. The Glenbar or Treflan spray should be followed by handweeding if resistant grass weeds are present. An application of TOK should be followed by handweeding where resistant grass weeds are present. In lowland rice the younger/smaller weeds are less difficult to remove. The process of weeding a lowland rice field involves "burying" the weeds into the mud. In including the treatments where handweeding preceded the Glenbar, TOK or Treflan treatments two advantages may be realized: (1) fewer man-days required to weed a unit area, and (2) since the herbicides will be applied later, residual effect may be expected to remain further into the crop season.

Data obtained from the two experiments are presented in Tables 3 and 4. There was very little variation in the number of man-days to weed the plots (1966 experi-

Table 4. The relative effectiveness of Glenbar, TOK and Treflan sprayed either before or after a handweeding, dry season, 1967.

TREATMENT	Effect on the crop Yield (Kg/Ha)	Dry wt. of weeds per 625 sq. cm. (g)[1] Sedges	Grasses	Broadleaved	TOTAL	Dry weight (g) of Echinochloa crus-galli per 18 sq. meter[2]
1. TOK, 4 kg/Ha at 5 days + 1 Hw at 25 days	5307	6.2	6.7	0.2	13.1	337
2. Hw at 20 days + TOK, 4 kg/Ha at 25 days	6010	3.5	0	2.7	6.2	155
3. Glenbar, 2 kg/Ha at 10 days + 1 Hw at 25 days	6138	11.7	0.2	6.5	18.4	107
4. Hw at 20 days + Glenbar, 2 kg/Ha at 30 days	5848	12.7	1.0	1.5	15.2	118
5. Glenbar, 2 kg/Ha at 10 days + 2,4-D, 1/2 kg/Ha at 30 days	5248	2.0	14.5	0.2	16.7	646
6. Treflan, 1 kg/Ha at 10 days + 1 Hw at 25 days	5859	16.0	0.5	1.0	17.5	108
7. Hw at 20 days + Treflan, 1 kg/Ha at 30 days	5668	18.5	2.0	3.0	23.2	206
8. Treflan, 1 kg/Ha at 10 days + 2,4-D, 1/2 kg/Ha at 30 days	6126	2.2	8.0	0	10.2	267
9. Handweeded 3 times	6181	0.7	0	0	0.7	5
10. Unweeded	5115	20.2	15.2	4.0	39.4	604

LSD (.05) = 677

[1]Taken at 70 days after transplanting. [2]Dry weight at harvest.

ment) prior to the application of the herbicides: 24.2, 23.2 and 20.3 man-days per hectare for the plots to be treated with Glenbar, TOK and Treflan, respectively. However, there were big differences in man-days required to weed the plots when weeding was done after herbicide application. It took 31.1 man-days per hectare to weed the Glenbar-treated plots; 21.1 for TOK-treated plots, and 16.9 for Treflan-treated plots. These data were taken as a reflection of the extent of control of susceptible species and inhibition of growth and development of the resistant species brought about by the respective herbicide treatment.

The yield data from the 1966 experiment were as expected. All treatments involving three herbicides immensely increased grain yield over the unweeded control. Also, yields from these plots compared favorably with the handweeded control. In the 1967 test, grain yield comparable to that from plots handweeded thrice were obtained from plots that were: (1) handweeded at 20 days plus TOK (4 kg/Ha) at 25 days; (2) Glenbar (2 kg/Ha) at 10 days plus handweeding at 25 days and (3) Treflan (1 kg/Ha) at 10 days plus 2,4-D (½ kg/Ha) at 30 days. The low yield obtained from plots treated with TOK at 5 days and then handweeded at 25 days was due to crop injury. The low yield from plots sprayed with Glenbar at 10 days plus 2,4-D at 30 days was due to insufficient grass control.

In the preliminary field screening of Ihara Chlos, Molinate, OCS-21799, TX-1120 and UC-22463 sprayed at different rates and times after transplanting the following herbicide treatments are worth further evaluation: 1 to 2 kg/Ha of OCS-21799 and TX-1120 applied 10 days after transplanting and 2 to 4 kg/Ha of Molinate at 5 days after transplanting (Table 5).

SUMMARY

1. The paper reports the results of four experiments, carried over a period of two years (1965 and 1966), designed to evaluate the effectiveness of Glenbar, TOK and Treflan for weed control in lowland rice. Results from a preliminary field screening of five "newer" herbicides are included.

2. Results strongly suggest the following herbicide treatments to be suitable for weed control in lowland rice:

a. Glenbar: 1-2 kg/Ha at about 10 days after transplanting. In the absence of resistant grass species (those propagated vegtatively), ½ kg/Ha 2.4-D should be applied at about 30 days after transplanting to control surviving sedges and broadleaved weeds. In the presence of resistant grass species, the Glenbar spray should be followed by one handweeding about a month after transplanting.

b. TOK: 2 kg/Ha at transplanting, or 4 kg/Ha at about 5 days after transplanting. These treatments (especially the latter) are likely to cause injury to the rice plants. In areas where resistant grass species are present a handweeding has to inevitably follow the TOK application. In such areas a better treatment might be to handweed at about 20 days and apply TOK at about 25 days.

c. Treflan: 1 kg/Ha sprayed at 10 days after transplanting. The Treflan spray should be followed by either ½ kg/Ha 2,4-D or handweeding. The 2,4-D spray is sufficient (where resistant grass species like *P. dilatatum* are absent) to control surviving sedges and *dicotyledonous* weeds. The Treflan should be followed by handweeding if resistant grass weeds are present.

3. It must be emphasized that Glenbar and Treflan are more effective when applied before the weeds emerge. This fact must be taken into consideration in using 10 days after transplanting as a guide for proper time of application.

4. Further evaluation of OCS-21799, TX-1120 and Molinate is suggested.

Table 5. Field screening of herbicides for lowland rice, dry season, 1967.

Herbicide	Kg/Ha	Days Applied[1]	Additional Weeding	Yield (Kg/Ha)
IHARA CHLOS	5	5	twice	4856
	6	5	twice	4669
	8	5	twice	4912
	5	10	twice	4884
	6	10	twice	4518
	8	10	twice	4451
MOLINATE:	2	5	one	5105
	3	5	one	4936
	4	5	one	5206
	2	10	one	5119
	3	10	one	4903
	4	10	one	4680
OCS-21799:	1	5	none	4528
	2	5	none	4348
	1	10	none	4099
	2	10	none	4858
TX-1120	1/2	5	one	4817
	1	5	one	5110
	1/2	10	one	4658
	1	10	one	4900
	2	10	none	5032
Handweeded Check	—	—	—	4891
Unweeded Check	—	—	—	3212
UC-22463:	4	5	twice	2929
	6	5	twice	2166
	8	5	twice	2167
	4	10	twice	2870
	6	10	twice	3055
	8	10	twice	2658
Handweeded Check	—	—	—	3795
Unweeded Check	—	—	—	2107

[1]Days after planting when herbicide treatment was applied.

Table 6. Chemical nature of herbicides evaluated for weed control in lowland rice.

Glenbar	O,S-dimethyl tetrachlorothioterephthalate
Treflan	trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine
TOK	2,4-dichlorophenyl-4-nitrophenyl ether
Ihara Chlos	Pentachlorophenol - 16% + methyl chlorophenoxy propionic acid - 0.75%
Molinate	Ethyl-1-hexamethyleneimine carbothiolate
OCS-21799	2-(4-chloro-O-tolyloxy)-N-methoxy acetamide
TX-1120	1 part O,S-dimethyl tetrachlorothioterephthalate + 2 parts methyl-2,3,5,6-tetrachloro-N-methoxy-N-methyl terephthalamate
UC-22463	3,4 plus 2,3-dichlorobenzyl methylcarbamate

EVALUATION OF HERBICIDES FOR WEED CONTROL IN UPLAND RICE

M. R. Vega, J. D. Ona and E. C. Paller, Jr.[1]

In the Philippines the average yield per hectare of upland rice is 788 kg. While the reasons behind the very low yield per unit area are numerous, principal among them is the weed problem. The experiments herein reported include a two-year field evaluation of herbicides (1965 and 1966) for weed control in upland rice.

MATERIALS AND METHODS

Three experiments are involved. Two of the experiments evaluated the effectiveness of Glenbar, Treflan and WL-9385-D; the third was a study of the efficacy of three "newer herbicides", TX-1120, SD-11831 and OCS-21799 as pre- or post-emergence sprays. The chemical nature of these herbicides are:

GLENBAR
O,S-Dimethyl tetrachlorothioterephthalate
TREFLAN
, , -trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine
WL-9385-D
2-azido-4-ethylamino-6-t-butylamino-s-triazine
OCS-21799
2(4-chloro-o-tolyloxy)-N-methoxy acetamide
SD-11831
4(methylsulfonyl)-2,6-dinitro-N,N-dipropylaniline
TX-1120
1 part O,S-dimethyl tetrachlorothioterephthalate + 2 parts methyl-2,3,5,6-tetrachloro-N-methoxy-N-methyl terephthalamate

All experiments were conducted in the upland fields of the Central Experiment Station, University of the Philippines. The soil in the station is classified as Lipa clay loam. The predominant weed species in the experimental area were: *Rottboellia exaltata* L.f., *Digitaria sanguinalis* (L.) Scop., *Eleusine indica* (L.) Gaertn., *Echinochloa colonum* (L.) Link, *Ipomoea triloba* L. *Celosia argentea* L., *Amaranthus spinosus* L. and *Cyperus rotundus* L.

Evaluation of Glenbar, Treflan and WL-9385-D. On the basis of results obtained from greenhouse tests performed in 1964, it was decided to study the performance of these three herbicides under field conditions. In the 1965 test, upland rice variety Palawan was drilled at the rate of 77 kg per hectare. The field was then subdivided into 2 x 5 m plots. A completely randomized block design with four replications was used. The experiment involved different concentrations and times of applications of the herbicides. All Glenbar and Treflan plots were sprayed with ½ kg/Ha 2,4-D amine as a supplementary treatment one month after planting. The best herbicide treatments from the 1965 experiment was further evaluated in 1966 using larger plots (6 x 23 m). As the experiment progressed it was decided to impose additional weeding operations upon the basic herbicide treatment. The final treatments may be seen in Table 4.

In both crop seasons, 90 kg N/Ha was applied in three equal portions at planting, 30 and 60 days after planting. The insecticides Sevin and endrin were applied at intervals during the season.

Evaluation of TX-1120, SD-11831 and OCS-21799. The experiment was designed as a preliminary field screening for three newer herbicides that became available for the 1966 crop season. Each herbicide was applied as a pre-emergence spray (2 days after planting) and as a post-emergence (12 days after planting). At each application date three concentrations were used, namely: 0.6, 1.1 and 2.2 kg/Ha. The plots treated with pre-emergence sprays of TX-1120 were given a follow-up spray of 0.6 kg/Ha 2,4-D one month after planting.

RESULTS AND DISCUSSION

Evaluation of Glenbar, Treflan and WL-9385-D. During the 1965 crop season some weed species notably *I. Triloba* have started to germinate 4 days after planting the rice seeds. By the time the herbicide application at 8 days was made many of the weed seedlings have emerged. Table 1 presents data on the effectiveness of three concentrations of Glenbar applied at three different dates. Glenbar is more toxic to the weeds when applied pre-emergence. Taking the average of all concentrations applied at each treatment date, reduction in weed population at 20 days after planting was 61.1, 27.7 and 22.2 percent for sprayings done at 1, 4 and 8 days after planting, respectively. Grass weeds are much more susceptible to Glenbar than are the sedges and the broadleaved (dicotyledonous) weeds. When treatment was done at 1 day after planting, Glenbar reduced grass weed population by 84 percent (average of 3 concentrations); the corresponding figure for sedges and broadleaved weeds taken together was only 30 percent. None of the treatments caused any visible adverse effect on the rice plants. When applied either at 1 or 4 days after planting all three rates of Glenbar significantly increased yield over that from the unweeded check plots. However, only plots sprayed with 2 kg/Ha at 1 day after planting plus ½ kg/Ha 2,4-D at 30 days gave yields statistically comparable to the yields from hand-weeded plots.

A summary of the data on the evaluation of Treflan is presented in Table 2. Treflan is best applied before the weed seeds germinate. For instance, at 20 days after planting an average reduction in weed population of 68 percent was recorded when spraying was done at planting. On the other hand, weed population was reduced to only 55 percent when the herbicide was applied 4 days after planting. The grass weeds are more susceptible to Treflan than are the broadleaved weeds and the sedges. Among the plots treated at 1 day, the grass weed population was 88 percent (average of two rates of applications) less than that present in the unsprayed plots; the corresponding figure for the sedges and broadleaved weeds was 55 percent. Numerous workers advocate the incorporation of Treflan. In this experiment, no added advantage was derived from incorporation. While there is evidence that incorporation may have resulted in better weed control, the yield data did not reflect this added advantage of incorporating Treflan into the soil. It is deduced that the weeds were sufficiently controlled even without incorporation. Data on rainfall may help explain the phenomenon. A 0.24 inch rain fell about five hours after spraying; and 0.46, 0.69, 0.12 and 0.04 inch two days before and after planting, respectively. The rains, especially those that fell shortly after spraying, must have accomplished what incorporation was supposed to accomplish. Highest yield was obtained when 1 kg/Ha Treflan was sprayed without incorporation immediately after planting, followed by ½ kg/Ha 2,4-D at one month after planting.

Table 3 presents data from the experiment on the relative effectiveness of two concentrations of WL-9385-D applied at three different stages of rice growth. While Glenbar and Treflan were more effective when applied prior to germination of weed seeds, it is evident that WL-9385-D is more potent when sprayed at the time the weed seedlings have started to emerge. Spraying done at 4 days after planting corresponded to this latter stage of weed development. Taking the two concentrations 3/4 and 1 kg/Ha as one, the herbicide reduced weed population by 43 percent when treatment was at 1 day. Reduction was as much as 77 percent when treatment was at 4 days. The yield data suggest that 0.75 kg/Ha was just effective kg/Ha.

Further evaluation of Glenbar, Treflan and WL-9485-D. The best Glenbar, Treflan and WL-9385-D treatments found in the 1965 test were the basic herbicide treatments applied in the 1966 experiment. A summary of the data obtained from the study are presented in Table 4. Within each plot given the basic herbicide treatment, 1/3 was weeded twice during the season; another was sprayed with 1/2 kg/Ha 2,4-D at one month after planting; while the last third of the plot was not given any additional treatment.

Treflan inhibited the germination of the rice seeds. This inhibition is reflected by the data on stand count taken 23 days after planting when a 59 percent reduction in stand was noted. In the 1965 test the same concentration of Treflan did not cause such phytotoxicity. The 1966 observation may be due to the occurrence of heavy rains shortly after herbicide application; e.g. 0.06, 0.70 and 0.22 inch fell at 1, 2 and 3 days after planting, respectively. Apparently, the herbicide was leached down to the level of the root zone of the crop. The tips of the first two leaves of rice seedlings treated with WL-9385-D turned brown and soon dried-up. The extent of drying was however only up to about 1/3 of the leaves; furthermore, the younger leaves and those that emerged subsequently were all normal. This slight toxicity to the crop was only temporary and did not affect subsequent growth and development of the rice plants. Glenbar did not cause any apparent injury to the rice.

The trend of grain yield among the Treflan and Glenbar plots was similar. Both herbicides applied at the same rate and time

Table 1. Field evaluation of herbicides for upland rice: Glenbar. (Palawan. 1965)

TREATMENT		EFFECT ON WEEDS					
		No. per 20 x 50 cm. at 20 days after planting				Dry Weight at harvest (g/0.5 sq. meter)	Yield of grain (Kg/Ha)
Days after planting	Kg/Ha	G[1]	S	B	TOTAL		
1	0.5	1.8	2.5	4.5	8.8	104.75	1789
	1.0	1.5	2.1	4.4	8.0	28.75	1871
	2.0	1.4	0.5	3.6	5.5	14.75	2247
4	0.5	5.3	3.8	2.8	11.9	58.75	1768
	1.0	4.8	3.3	1.8	9.9	54.75	1679
	2.0	2.0	4.0	2.1	8.1	63.00	1585
8	0.5	8.5	4.6	4.0	17.1	291.25	950
	1.0	8.5	2.5	3.4	14.4	295.25	888
	2.0	7.4	1.0	2.1	10.5	257.00	1232
Stam F– 4 + 2,4-D		3.8	2.0	3.2	9.0	133.50	1416
Handweeded Check		0	0	0	0	8.00	3028
Unweeded Check		10.1	3.4	4.6	18.1	455.00	355

[1]G = grass weeds; S = sedges; B = dicot weeds. Grain yield - HSD 0.05 = 966

Table 2. Field evaluation of herbicides for upland rice: Treflan (1965)[1]

TREATMENT	EFFECT ON WEEDS					
	No. per 20 x 50 cm. at 20 days after planting				Dry Weight at harvest (g/0.5 sq. meter)	Yield of grain (Kg/Ha)
	G[2]	S	B	TOTAL		
1 kg/Ha at planting incorporated	1.0	2.5	6.1	9.6	13.75	1903
1 kg/Ha at planting not incorporated	1.9	0.6	7.6	10.1	20.25	1991
2 kg/Ha at planting incorporated	0.5	4.9	4.6	10.0	33.00	1724
2 kg/Ha at planting not incorporated	1.1	3.9	5.8	10.8	23.75	1816
1 kg/Ha 4 days after planting	3.3	3.6	8.4	15.3	34.00	1539
2 kg/Ha days after planting	1.5	2.1	8.4	12.0	5.25	1697
Stam F-34 + 2,4-D	12.8	6.0	5.6	24.4	170.25	669
Handweeded Check	8.3	10.3	4.0	22.6	0.75	2111
Unweeded Check	12.5	5.6	12.5	30.6	199.25	321

[1]Incorporation of Treflan was done with the use of a Japanese rotary weeder.

[2]G = grass weeds; S = sedges; B = dicot weeds. Grain yield HSD 0.05 = 605.

Table 3. Field evaluation of herbicides for upland rice: WL-9385-D (1965)

TREATMENT Days after planting	Kg/Ha	EFFECT ON WEEDS No. per 20 x 50 cm. at 20 days after planting G^1	S	B	TOTAL	Dry Weight at harvest (g/0.5 sq. meter)	Yield of grain (Kg/Ha)
1	0.75	8.0	6.5	10.0	24.5	26.43	836
	1.0	7.1	7.3	11.8	26.2	19.65	1326
4	0.75	4.5	4.0	5.0	13.5	20.25	2083
	1.0	1.8	2.8	2.0	6.6	9.50	1995
8	0.5	-	-	-	-	100.50	1061
	1.0	-	-	-	-	87.00	1453
Stam F-34 + 2,4-D		9.8	16.0	22.6	48.4	194.50	342
Handweeded Check		4.1	10.3	4.5	18.9	5.50	2733
Unweeded Check		10.1	15.3	19.0	44.4	244.00	301

[1]G = grass weeds; S = sedges; B = dicot weeds. Grain yield HSD 0.05 = 523

of application used seemed capable of replacing only one handweeding. In the experiment, low yields obtained from plots treated with Glenbar alone was attributed to insufficient weed control; however, the reason behind low yields from corresponding Treflan plots was the adverse effect of this herbicide on the germination of the crop. WL-9385-D has shown very satisfactory performance as a herbicide for upland rice for the past two crop seasons (1965 and 1966). While an additional treatment was not deemed necessary during the 1965 test, in the 1966 test the use of 2,4-D at ½ kg/Ha as a follow-up spray proved advantageous. Such an observation is attributed to the less favorable environmental conditions for rice growth in this season which may have resulted in greater competition from the surviving weed species. The surviving weed species were mainly those susceptible to the chlorophenoxies.

Table 4. The effectiveness of Glenbar, Treflan and WL-9385-D for weed control in upland rice (1966)

TREATMENT Main Treatment	Additional	EFFECT ON THE WEEDS Weed counts/2500 sq. cm. G^1	S	B	TOTAL	Dry Weight g/30 x 100 sq. cm.	EFFECT ON THE CROP Stand count 2500 sq. cm.	Grain Yield (Kg/Ha)
1 kg/Ha Treflan at planting	–	4.2	25.5	3.5	33.2	87.7	47.0	380
	2 weedings							1042
	½ kg/Ha 2,4-D							951
2 kg/Ha Glenbar at planting	–	10.0	10.2	2.7	22.9	230.7	109.0	372
	2 weedings							1041
	½ kg/Ha 2,4-D							954
3/4 kg/Ha WL-9385-D at 4 days after planting	–	8.7	12.0	0.7	21.4	102.2	96.2	944
	2 weedings							1213
	½ kg/Ha 2,4-D							1129
Handweeded	2 weedings					36.0	107.2	929
	3 weedings	0	0	0	0			1020
	2 weedings + ½ kg/Ha 2,4-D							1273
Unweeded Check	–	41.0	24.2	26.5	91.7	244.0	94.7	210

[1]G = grass weeds; S = sedges; B = dicot weeds. Grain yield HSD 0.05 = 523.

Evaluation of TX-1120, SD-11831 and OCS-21799. Data gathered from the experiment are summarized in Table 5. SD-11831 and TX-1120, sprayed pre-emergence, especially the former, were very effective in preventing the germination of grass weeds. A count taken at 30 days after planting showed that at 1.1 kg/Ha, reduction in grass weed population was 97 and 77 percent, respectively. With OCS-21799 a 2.2 kg /Ha rate was needed to reduce grass weeds 68 percent; at this concentration, however, inhibition of rice emergence was practically 100 percent. SD-11831 was likewise quite effective in inhibiting the emergence of broadleaved weeds and sedges, TX-1120 was not as potent against the latter group of weeds; the supplemental 2,4-D spray was mainly to control the surviving sedges and broadleaved weeds. A pre-emergence application of TX-1120 at 0.6 kg/Ha plus a post-emergence spray of ½ kg/Ha 2,4-D gave yields comparable to plots handweeded three times. Considering the yield data, only 1.1 kg/Ha of SD-11831 proved effective, 0.6 kg/Ha did not provide sufficient weed control, while 2.2 kg/Ha was too toxic to the rice plants.

Only OCS-21799 proved fairly effective as a post-emergence spray. This herbicide, even at the lowest concentration used in the experiment (0.6 kg/Ha), was sufficiently toxic to the sedges and broadleaved weeds. It was, however, not as effective against the grass weeds. Yields from the OCS-21799 treated plots were comparable to the yields from plots handweeded three times.

Table 5. The effects of TX-1120, SD-11831 and OCS-21799 on weeds and yield of upland rice (1966)

TREATMENT	(Kg/Ha)	No. of weeds per 2500 sq. cm.				Dry Weight at harvest	Yield (Kg/Ha)
		G[1]	S	B	TOTAL		
A. Pre-emergence TX-1120	0.6	5.5	14.0	8.7	28.2	222.2	1213
	1.1	4.0	16.7	8.5	29.2	102.0	1175
	2.2	3.7	14.5	6.2	24.4	103.7	1365
SD-11831	0.6	2.2	8.0	7.7	17.9	251.0	835
	1.1	0.5	7.0	2.0	9.5	123.5	1092
	2.2	0.2	6.7	3.5	10.4	141.2	137
OCS-21799	0.6	14.0	9.0	6.5	29.5	360.2	382
	1.1	14.0	7.7	4.7	26.4	343.2	215
	2.2	5.5	2.5	1.0	9.0	239.2	433
B. Post-emergence TX-1120	0.6	9.5	16.7		31.9	265.7	417
	1.1	11.2	11.2	11.0	33.4	222.5	375
	2.2	10.5	13.0	12.7	36.2	199.7	566
SD-11831	0.6	5.0	11.2	4.1	20.9	243.5	753
	1.1	10.7	10.0	4.0	4.7	196.7	382
	2.2	17.0	5.7	14.0	36.7	418.5	323
OCS-21799	0.6	10.7	5.7	2.5	17.9	162.5	1126
	1.1	7.7	5.5	0.0	12.7	153.5	1203
	2.2	13.2	0.0	0.0	13.2	313.5	1030
Unweeded	–	17.5	16.0	16.5	50.0	353.2	278
Weeded	–	–	–	–	–	75.5	1351

[1]G = grass weeds; S = sedges; B = dicot weeds.

SUMMARY

1. Two experiments which evaluated the effectiveness of Glenbar, Treflan and WL-9385-D for weed control in upland rice are reported. A preliminary field screening of TX-1120, SD-11831 and OCS-21799 is likewise described.

2. For two seasons, WL-9385-D has very satisfactory performance as a pre-emergence herbicide for upland rice. A subsequent 2,4-D spray at about a month after planting may proved advantageous where the WL-9385-D treatment did not sufficiently inhibit emergence of broadleaved weeds and sedges.

3. Glenbar at 2 kg/Ha and Treflan at 1 kg/Ha apparently can only replace one handweeding. Because of its toxic effect on rice germination, Treflan should be used in upland rice with care.

4. In a preliminary field screening trial, a pre-emergence spray of SD-11831 at 1.1 kg/Ha and of TX-1120 at 0.6, 1.1 or 2.2 kg/Ha are promising treatments for weed control in upland rice. The latter herbicide should be followed by a ½ kg/Ha of 2,4-D (or MCP) at about a month after planting. Of the three herbicides tested, only OCS-21799 proved suitable as a post-emergence herbicide for upland rice.

WEED CONTROL IN RICE IN THE UNITED STATES

Roy J. Smith, Jr.[1]

Weeds reduce the potential production of rice in the United States–the damage even exceeds that from diseases and insects combined (Table 1). Weeds reduce rice production by 17 percent as compared with 11 percent for both diseases and insects. Annual losses caused by weeds in the United States rice fields and the cost of their control approximated $70 million during 1951-1960 (Table 2).

Both cultural and chemical methods of controlling weeds are integral parts of rice production. Cultural methods include use of weed-free crop seed, rotating crops, leveling land, tillage of seedbeds before seeding the crop, selecting seeding methods that reduce weed problems, and managing water and fertilizer properly. When cultural methods do not control weeds effectively, herbicides can be used advantageously. However, combinations of cultural and chemical practices, such as are used by most commercial rice growers in the United States, are more effective than either practice used alone.

In this paper, I will emphasize the interdependence and interrelations of cultural and chemicals methods of weed control in rice production.

THE WEED PROBLEM

Weeds compete with rice for light, nutrients, water, and other growth requirements. They reduce grain yields, lower the market value of the crop by reducing quality, and increase the cost of production, harvesting, drying, and cleaning.

Barnyardgrass[2] is the most common and troublesome weed in rice in the United States. Others are listed in Table 3.

Both terrestrial and aquatic weeds infest rice. Terrestrial weeds usually germinate before the rice is flooded or while it is drained, but they may grow and reproduce in flooded soil. Representative terrestrial weeds are barnyardgrass, curly indigo, Mexican-weed, and sesbania. Aquatic weeds usually germinate, grow, and reproduce in flooded soil. Common aquatic weeds in rice fields are ducksalad, redstem, waterhyssop, and some sedges.

Losses caused by weeds in rice are important in determining how much can be profitably expended for control. If the cost of controlling the weed exceeds the increase in income from controlling the weed, then the weed control practice will be of little benefit.

We have collected data on yield losses caused by certain weeds. Good stands of rice compete better than poor stands with barnyardgrass. For example, 1 grass plant per square foot in a rice stand of 3 plants per square foot reduced yields 57 percent. The same grass stand in a rice stand of 31 plants per square foot reduced yields only 25 percent. Experiments show that 1 barnyardgrass plant per square foot competing with a good stand of rice reduced rice yields enough to warrant cost of control with herbicides.

Experiments at Stuttgart, Arkansas, showed that barnyardgrass competed significantly with rice during the early stages of rice development. For example, barnyardgrass competing with rice for about 7 weeks reduced rice yields about 40 percent; competition for even 3 weeks reduced rice yields about 10 percent. Therefore, this weed should be controlled as soon after emergence as possible. Barnyardgrass is now controlled with herbicides during the first 2 weeks after emergence.

Sesbania and curly indigo compete seriously only after they overtop the crop at about 12 weeks after emergence. In experiments at Stuttgart, Arkansas, both weeds competing with rice during the heading and grain formation stages reduced yields about 20 percent as compared to 0 to 10 percent for competition up to that stage. Because these weeds are usually controlled with phenoxy herbicides 5 to 10 weeks after rice emergence, they do not affect rice yields greatly. Both weeds should be controlled, however, before panicles emerge.

CULTURAL METHODS OF WEED CONTROL

Weed-Free Crop Seeds

Planting weed-infesting crop seed is one of the major ways by which clean fields become infested with weeds. Red rice, a serious weed in rice fields, is spread largely by using rice seed contaminated with grains

Table 1. Estimated average annual losses in rice in the United States due to pests, 1951-60

Pest	Reduction	Losses from potential production[1] Quantity	Value
	Percent	1,000 cwt	1,000 dollars
Weeds	17	7,200	45,700
Diseases	7	3,900	18,800
Insects	4	2,200	10,700

[1] Losses taken from USDA Agricultural Handbook 291, Losses in Agiculture, 1965.

Table 2. Estimated average annual losses in rice due to weeds and cost of controlling them by cultural and chemical methods in the United States, 1951-60.

Type of loss	Value of loss[1]
	1,000 dollars
Production	45,700
Cultural methods of control	23,100
Chemical methods of control	900
Total	69,700

[1] Losses taken from USDA Handbook 291, Losses in Agriculture, 1965.

[1]Research Agronomist, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the Arkansas Agricultural Experiment Station, Stuttgart, Arkansas, U.S.A.

[2]Scientific names of weeds are given in Table 3.

Table 3. Common rice field weeds and their susceptibility to control by herbicides.

Weed		Herbicide and control					
Common name	Scientific name	propanil	molinate	2,4-D	MCPA	2,4,5-T	silvex
Arrowhead	*Sagittaria* L. spp.	Poor	Poor	Good	Good	Good	Good
Barnyardgrass	*Echinochloa* Beauv. spp.	Excellent	Excellent	Poor	Poor	Poor	Poor
Beakrush	*Rhynchospora corniculata* (Lam.) Gray	Fair	Poor	Good	Good	Good	Good
Brachiaria	*Brachiaria platyphylla* (Griseb.) Nash	Excellent	Fair	Poor	Poor	Poor	Poor
Bulrush	*Scirpus* L. spp.	Poor	Poor	Poor	Poor	Poor	Poor
Burhead	*Echinodorus cordifolius* (L.) Griseb.	Poor	Poor	Excellent	Excellent	Excellent	Excellent
Cattail	*Typha* L. spp.	Poor	Poor	Fair	Fair	Fair	Fair
Crabgrass	*Digitaria* Heist. spp.	Excellent	Excellent	Poor	Poor	Poor	Poor
Curly indigo	*Aeschynomene virginica* (L.) B.S.P.	Good	Poor	Fair	Fair	Excellent	Excellent
Ducksalad	*Heteranthera* R. & P. spp.	Poor	Poor	Excellent	Fair	Fair	Fair
Fimbristylis	*Fimbristylis* Vahl spp.	Excellent	Poor	Excellent	Excellent	Excellent	Excellent
Gooseweed	*Sphenoclea zeylanica* Gaertn.	Poor	Poor	Fair	Fair	Fair	Fair
Jointed flatsedge	*Cyperus articulatus* L.	Poor	Poor	Fair	Fair	Fair	Fair
Knotgrass	*Paspalum* L. spp.	Fair	Poor	Poor	Poor	Poor	Poor
Mexican-weed	*Caperonia castaneaefolia* (L.) St. Hil.	Poor	Poor	Fair	Fair	Good	Good
Morningglory	*Iponoea* L. spp.	Poor	Poor	Excellent	Excellent	Excellent	Excellent
Paragrass	*Panicum purpurascens* Raddi	Excellent	Good	Poor	Poor	Poor	Poor
Red rice	*Oryza sativa* L.	Poor	Poor	Poor	Poor	Poor	Poor
Redstem	*Ammannia* L. spp.	Poor	Poor	Excellent	Excellent	Excellent	Excellent
Sesbania	*Sesbania exaltata* (Raf.) Cory	Good	Poor	Excellent	Fair	Excellent	Excellent
Smartweed	*Polygonus* L. spp.	Poor	Poor	Fair	Fair	Fair	Fair
Spikerush	*Eleocharis* R. Br. spp.	Good	Good	Good	Good	Good	Good
Sprangletop	*Leptochloa* Beauv. spp.	Fair	Good	Poor	Poor	Poor	Poor
Texas-millet	*Panicum texanum* Buckl.	Excellent	Good	Poor	Poor	Poor	Poor
Umbrellasedge	*Cyperus* L. spp.	Fair	Poor	Good	Good	Good	Good
Waterhyssop	*Bacopa rotundifolia* (Michx.) Wettst.	Poor	Poor	Excellent	Excellent	Excellent	Excellent
Waterplantain	*Alisma triviale* Pursh	Poor	Poor	Excellent	Excellent	Good	Good
Waterprimrose	*Jussiaea* L. spp.	Poor	Poor	Fair	Fair	Fair	Fair

Excellent–One application at normal rates kills 80 to 100% of the weeds. Normal rates for propanil, 3 lb/A; molinate, 3 lb/A; phenoxy *herbicides, 1 lb/A.*

Good–One application at rates higher than normal kills 60 to 80% of the weeds

Fair–Weed is not controlled selectively in rice, but can be controlled with high rates or with repeated applications on levees and in canals where rice injury is not important.

Poor–Weed is not controlled even at high rates.

of red rice. Other weeds, such as sesbania, curly indigo, barnyardgrass, Mexican-weed, and beakrush, are also spread through use of weed-contaminated rice seed. After weeds infest a rice field they are difficult to control. The use of herbicides to control weeds in the rice crop helps in the production of weed-free crop seed. Control of barnyardgrass, brachiaria, and other annual grasses with *propanil*[3], and control of curly indigo, sesbania, Mexican-weed, umbrellasedge, spikerushes, beakrush, and other broadleaf and sedge weeds with phenoxy herbicides, can reduce weed seed content of rice.

Crop Rotations

Properly managed rotations are important for weed control. The occurrence of a weed species in rice is often associated with the rotation practiced. In Louisiana and Texas, native pastures are often poorly drained. Poor drainage favors growth of perennial weeds such as spikerush and jointed flatsedge. Rice following native pastures may be infested with these two perennial weeds. Improved pastures, which are well drained, and heavily fertilized, do not have the same weeds as native pastures. Heavy infestations of barnyardgrass are associated with rice grown in a rotation after improved pastures,

[3]Chemical names of herbicides are given in Table 4.

but the problem of perennial weeds is less serious in this rotation than in native pastures.

In Arkansas, rice-soybean-oat or rice-soybean rotations reduce infestations of barnyardgrass, sesbania, curly indigo and ducksalad. Weeds in a soybean crop in a rice-soybean-oat rotation can be controlled by combinations of cultural practices with preemergence and postemergence herbicides. Broadleaf weeds in the oat crop can be controlled with phenoxy herbicides, and summer fallowing after oat harvest controls weeds such as barnyardgrass, red rice, sesbania, and curly indigo.

Rotations of rice with an unirrigated row crop (such as safflower) or with fallow are valuable in California for controlling cattails, bulrush, spikerush, and other perennial weeds with large rootstocks. For fallow to successfully control these weeds, the soil must be dried to a depth of 12 inches.

The combination of crop rotations and herbicides is more effective in controlling weeds in all crops in the rotation than either practice used alone. Preemergence and postemergence herbicides applied on row and pasture crops rotated with rice also reduce weeds in the rice crop. Likewise, propanil, molinate, and phenoxy herbicides used to control grass, broadleaf, and sedge weeds in the rice crop reduce weed infestations in crops rotated with rice.

Land Leveling and Levee Construction

Land leveling, combined with construction of levees to permit uniform depth of flood, is important in a weed control program. The land should be free of hummocks, ridges, sloughs, and hollows.

Aquatic weeds are most numerous in low areas where surface drainage is inadequate. Other weeds, including barnyardgrass, sesbania, and curly indigo, may be more serious on ridges where water does not cover the land adequately. Therefore, land leveling and levee construction, to eliminate low and high areas in the rice field, and to maintain 4 to 8 inches of water, reduce weeds. Moreover, leveled land requires fewer levees which reduces places for the growth and reproduction of weeds.

Herbicides reduce problems with weeds on rice fields with improper land leveling and levee construction. Silvex, 2,4-D, 2,4,5-T, and MCPA control aquatic and sedge weeds associated with low or wet areas. Weeds such as barnyardgrass, sesbania, curly indigo, and morningglory growing on high areas in the rice paddy or on levees may be controlled with propanil and phenoxy herbicides.

Seedbed Preparation

Elimination of weeds is a primary goal in preparing seedbeds. The seedbed may be prepared in many ways––plowing, disking, harrowing, rotary tilling, and combination methods. The best method to use depends on the soil, rotation, previous crop, seeding method, and perhaps other conditions. Regardless of the method used, preparation of the seedbed should eliminate all weed growth up to the time of seeding rice.

Thorough seedbed preparation helps to control all weeds that infest rice fields, and increases the effectiveness of herbicides used after the rice crop germinates and emerges. Killing established weeds during seedbed preparation reduces the problem to weeds which must either germinate from seed, or emerge from root or stem parts after the rice is seeded. These younger weeds are very susceptible to herbicides during the early part of the rice-growing season.

Seeding

The method of seeding influences weed problems. Barnyardgrass associated with drill-seeded or dry-broadcast-seeded rice is difficult to control by cultural or mechanical methods. Water-seeding, initiated in California to control barnyardgrass, reduces problems with annual grasses. In Louisiana pre-sprouted rice seeds are sown in the water with aerial equipment on a well prepared and smoothed-in-the-water seedbed; then in 1 or 2 days the rice field is drained. This method of seeding reduces barnyardgrass infestations; and draining soon after sowing helps control aquatic weeds such as ducksalad, waterhyssop, and redstem.

Herbicides are essential to effective control of weeds that may develop under any seeding method. Propanil controls annual grasses that may infest dry-seeded rice, and phenoxy herbicides control broadleaf, sedge, and aquatic weeds that may develop in water-seeded rice.

Water Management

Flooding rice to a depth of 4 to 8 inches when it is in the seedling stage helps control barnyardgrass and other annual grasses. The barnyardgrass should be in the 1- to 3-leaf stages, and water should remain on the field 1 to 3 weeks to kill it. High water temperatures (95°F or above) facilitate control of annual grasses, presumably because of the low oxygen content of warm water. Rice plants may be weakened by deep water and prolonged flooding. Also deep flooding of young rice when the water temperature exceeds 95°F may scald and kill the rice. Moreover, rice growing on calcareous or alkaline soil may be killed if flooded in the early stages of growth. Early flooding to control grass weeds, therefore, has a narrow margin of selectivity and must be used with caution. Herbicides can be effective where water management practices fail to control weeds.

In a field experiment in California, barnyardgrass and spikerush were controlled in water-seeded rice by continuous flooding to a depth of 6 inches. Where the water was lowered from 6 to 3 inches at 2 weeks after planting, barnyardgrass infested the plots; when the water was lowered at 4 weeks, barnyardgrass was controlled but spikerush invaded the plots. Where deep water cannot be maintained on the rice for extended periods, herbicides can be used to control weeds. If barnyardgrass develops after water has been lowered or drained from rice fields, it can be controlled with propanil. If spikerush develops, it can be controlled with phenoxy herbicides.

Timely and thorough draining of the water from rice fields helps control algae. Draining the water as soon as green areas of algal growth appear on the soil followed by alternate re-flooding and draining until the rice plants are 12 to 18 inches tall reduces algal growth. However, alternate flooding and draining may allow annual grasses to germinate and infest the rice field. Propanil can be used to control these annual grasses.

Herbicides may be combined advantageously with water management practices. Such combination practices are changing water management practices in the United States. A deep-water culture may be changed to a shallow-water culture where effective herbicides are available. Rice seedlings grown in a shallow-water culture are stronger and can compete better with weeds. Moreover, rice produces higher yields if grown in shallow water. A shallow-water culture used jointly with chemical weed control offers unusual opportunity for conserving water and lowering the cost of rice production.

Fertilizer Management

Phosphate or nitrogen applied directly to rice stimulates growth of many weeds, including barnyardgrass, ducksalad, and algae. But potash applied directly to rice apparently has little or no effect on growth of weeds.

Time and method of applying phosphate are very important when barnyardgrass and other grass-weed seeds infest rice fields in the southern United States. Phosphate applied before dry-seeding rice stimulates growth of young grass plants. Where fields have a history of severe infestations of barnyardgrass, phosphate should be applied to a crop in the rotation other than rice or applied just before early flooding of rice.

Where applied phosphate has stimulated weed growth, propanil and phenoxy herbicides can reduce the weed infestations. Herbicides, therefore, are important in alleviating weed problems caused by improper applications of fertilizer.

Early to mid-season applications of nitrogen are often advantageous in the absence of grass weeds. However, if barnyardgrass is present, nitrogen applied early will stimulate grass growth and enhance weed competition. Herbicides, therefore, are helpful if nitrogen is to be applied early. Controlling barnyardgrass and other annual grasses with propanil, permits timely application of nitrogen during the early growth stages of rice.

CHEMICAL METHODS OF WEED CONTROL

Chemical control of broadleaf weeds in rice began with the use of 2,4-D in the late 1940's. In 1966, about half of the rice crop in the United States was sprayed with phenoxy herbicides to control aquatic, broadleaf, and sedge weeds.

CIPC, which fails to control broadleaf weeds, was used in 1960 and 1961 in Arkansas to control grass weeds in rice. Critical requirements for effective grass-weed control without crop injury restricted its use to a small acreage.

In 1959, experiments in Arkansas with propanil indicated that it effectively controlled certain young annual grass and broadleaf weeds in rice. Rice farmers, in cooperative trials with commercial chemical companies, used propanil in commercial fields on about 20,000 acres in 1961. In 1962, propanil was recommended by the Agricultural Extension Service in rice-growing States and farmers treated approximately 15 percent of the rice acreage (Table 5). Since 1961, the use of propanil by commercial rice growers has steadily increased to about 80 percent of the total acreage. Moreover, per-acre yields of rice have increased by approximately 900 lb/A since the advent of propanil (Table 5). This increase in yield is valued at about $85 million for the rice industry in the United States.

Better control of weeds, although not solely responsible, was a vital factor in bringing about this phenomenal increase in yields. Also herbicides, properly used, facilitate good management of other rice production practices.

Controlling Grass and Broadleaf Weeds

In the United States high yields are essential to the profitable production of rice. The cost of components of production—land, labor, machinery, fertilizer, and pesticides—is high. Therefore, the farmer must make a high yield to stay in business. Herbicides that will control grass, broadleaf, and other weeds in the early growing season are essential to profitable production.

Propanil

Propanil controls many grass, broadleaf, sedge, and aquatic weeds in rice (Table 3). It controls weeds most effectively when they are in the early vegetative stages of growth.

Propanil is a selective postemergence herbicide, but fails to control weeds that germinate and emerge after treatment. Rates of 3 to 5 pounds per acre control weeds 2 to 3 inches tall effectively. It is effective on weeds that grow rapidly, but not on weeds that grow slowly because of dry soil or low temperatures. Irrigation before treatment, or delaying treatment until after temperatures rise stimulate weed growth and increase the susceptibility of weeds. If delays in treating permit stunted grass weeds to reach the 4- or 5-leaf stage, rates of 5 to 6 lb/A may be required for good control.

Propanil is usually applied, in about 10 gallons per acre of water solution, with fixed-wing or helicopter aerial spray equipment. Because propanil is absorbed by the foliage of the weed plants, the spray must cover the foliage completely. Moreover, in water-seeded rice, the irrigation water must be lowered or drained to expose the weeds to the spray. Because propanil affords no preemergence or residual control of weeds, flooding the rice field 2 to 4 days after treatment is required to prevent more weeds from germinating and emerging.

Propanil and postemergence insecticides such as carbaryl,[4] parathion, and methyl parathion applied to rice within 14 days of each other may injure rice and reduce stands. Chlorinated hydrocarbon insecticides such as endrin, dieldrin, aldrin, and DDT, interact less with propanil on rice than carbamate or phosphate insecticides, but considerable yellowing and burning of the rice foliage may result. These less toxic insecticides may be applied safely 7 days before or after a propanil treatment. Rice that has had an aldrin seed treatment may be sprayed safely with propanil.

[4]Chemical names of insecticides are given in Table 4.

Propanil-preemergence herbicide mixtures

Since propanil affords no residual control of weeds, new herbicides or combinations are needed, to control both emerged weeds and those which germinate for several weeks after treatment, so that flooding after treatment need not be as early as with propanil. Moreover, early flooding may not be advisable for rice grown on calcareous or alkaline soils since it may be damaged seriously if flooded continuously when the plants are small.

Half-rate mixtures of propanil and the residual herbicides 0–93, D–63, or D–97, applied when the largest weeds are ¼ to 1 inch tall, controlled emerged weeds, and those that germinated for about 5 weeks after treatment. Hence, mixtures of propanil and a residual herbicide, when applied before all weeds emerged controlled weeds as well as propanil when applied after all weeds emerged. Mixtures had an added advantage over propanil in that they controlled germinating weeds for several weeks after treatment and eliminated the requirement of early flooding after treatment. Such residual weed control should be useful in rice grown on calcareous or alkaline soils, or in other rice that cannot be flooded soon after it is treated with a herbicide.

Molinate

Molinate, a new herbicide, generally controls barnyard grass as well as propanil; in cool weather it is more effective than propanil. Incorporated in the soil at 3 lb/A before planting water-seeded rice, or postemergence after flooding dry-seeded rice, it controls barnyardgrass without injuring rice significantly.

Applied postemergence after flooding, it controls grass in the 2- and 4-leaf stage, if flooding is continued for about 1 week. Good control of grass in the tillering stage requires continuous flooding for 2 to 3 weeks. Molinate, applied postemergence, does not control weeds on the levees. Postemergence propanil or a dark-plastic covering on the levees will control weeds. Levees of plastic sheets supported by stakes eliminate soil levees and areas for growth of weeds. Molinate controlled some grass, broadleaf, and sedge weeds less than propanil (Table 3). It controlled barnyardgrass when the flood was held for 1 week and then drained for 3 weeks; however, rice fields drained for 4 weeks became infested with barnyardgrass.

The residual weed control that molinate offers, and its effectiveness during periods of cool temperatures, should be important in a weed control program.

Controlling Broadleaf Weeds with Phenoxy Herbicide

The phenoxy herbicides (2,4-D, MCPA, 2,4,5-T, and silvex), applied postemergence, control most broadleaf, aquatic, and many sedge weeds that infest rice. They do not control grass weeds and some sedges (Table 3). These herbicides are applied by ground or aerial equipment, either as amine or low-volatile ester formulations, at ½ to 1½ pounds acid equivalent per acre. The rate depends on the weed species and stage of growth of the rice.

Stage of growth of rice

The stage of growth greatly influences the response of rice plants to phenoxy herbicides. Very young rice (from emergence to 3 weeks after emergence) is injured severely or killed by phenoxy herbicides at rates required to control weeds. Rice treated in the early-tillering, late-jointing, booting, or heading stages may be seriously inhibited. Rice in the late-tillering to early-jointing stages is usually not injured by phenoxy herbicides. For mid-season varieties (Bluebonnet 50, Starbonnet), this "tolerant" stage usually occurs 8 to 10 weeks after emergence; 7 to 9 weeks for short-season varieties (Nato, Nova 66), and 5 to 6 weeks for very-short-season varieties (Belle Patna, Bluebelle, Vegold). In a 6-year investigation at Stuttgart, Arkansas, 2,4-D applied at ¾ and 2 pounds per acre to rice in the early-tillering and booting stages of growth, reduced rice yields about 17 percent. Yields were not affected, however, if the rice was treated in the late-tillering or early-jointing stages of growth.

Kind of phenoxy herbicide

Rice responds differently to postemergence application of phenoxy herbicides. MCPA is less toxic than 2,4-D, especially when applied during the early stages of growth. When mid-season varieties of rice are 4 to 8 weeks old, 2,4,5-T and silvex are less phytotoxic than 2,4-D or MCPA. Silvex and 2,4,5-T did not reduce yields when applied at early- and late-tillering and jointing stages of growth, but they reduced yields when applied at the booting stage. All these herbicides reduce yields severely when applied during the booting and heading stages.

Phenoxy herbicides may cause vegetative malformation in rice. Rice treated with 2,4-D at the early-tillering stage grew tubular leaves and malformed panicles; but rice treated with MCPA, 2,4,5-T, and silvex at the same stage appeared normal. All these herbicides applied at any stage may injure roots moderately to severely; may cause the rice plant to turn dark green soon after spraying if applied to early-tillering rice; or cause chlorosis and yellowing if applied to booting or heading rice.

Weeds respond differently to 2,4-D, MCPA, 2,4,5-T, and silvex (Table 3). For example, sesbania is very susceptible to 2,4-D and 2,4,5-T, but curly indigo is somewhat resistant to 2,4-D and susceptible to 2,4,5-T. Ducksalad, however, is more susceptible to 2,4-D than to 2,4,5-T. Where several species of weeds varying in susceptibility to a herbicide are present, mixtures of phenoxy herbicides may be used effectively. Mixtures of 2,4-D and 2,4,5-T are often more effective than either herbicide used alone.

In Southern rice-growing areas, aquatic weeds, such as ducksalad, waterhyssop, and redstem, may become a serious problem before rice reaches the "tolerant" stage. Silvex or 2,4,5-T controls these weeds safely when the rice is in the early-tillering stage or 4 to 6 weeks old. At this stage, silvex and 2,4,5-T should not be applied at more than 1 pound per acre and 2,4-D should not be applied at all. At rates of ¼ to 1 pound per acre, 2, 4, 5-T and silvex will not control ducksalad completely. Where ducksalad is abundant, a second treatment with 2, 4-D at 1 pound per acre may be required when the rice reaches the "tolerant" stage of growth.

Method of seeding and water management

When phenoxy herbicides are applied at ¼ to 1½ pounds per acre during the "tolerant" stage, method of seeding and water management usually do not influence the response of rice to these herbicides. Seeding method and water management may significantly affect the response if the herbicides are applied in the "susceptible stages," especially rice 3 to 6 weeks old. When water-seeded rice 3 to 6 weeks old is to be sprayed with phenoxy herbicides, a shallow flood on the rice field reduces damage to the rice. The stage of rice development at the time of applying phenoxy herbicides, however, is much more important than seeding method or water management.

Water management may affect the response of weeds to phenoxy herbicides. If water covers low-growing aquatic weeds such as ducksalad, redstem, and waterhyssop at spraying time, the weeds may not be controlled because the herbicide does not contact the weeds adequately. If weeds are growing slowly because of dry soil or for other reasons, they may not be controlled. The water should be drained from the field no more than 3 to 6 days before spraying to insure enough soil moisture for rapid growth of weeds.

Nitrogen management

When phenoxy herbicides are applied at the "tolerant" stage of rice, nitrogen applications should be carefully timed to avoid injury to rice. Rice may be injured if the nitrogen is applied 10 to 15 days before or 10 to 15 days after the herbicide.

At Stuttgart, Arkansas, application of nitrogen 15 days before the herbicides stimulated growth of rice in 4 or 5 days. By the time herbicides were applied, rice was green and growing rapidly. The herbicide caused chlorosis and reduced yields. The rice was not injured if nitrogen was applied either 5 days before or 5 days after the herbicide, but yields were reduced about 20 percent when nitrogen was applied 15 days after applying 2, 4-D or 2, 4, 5-T in the "tolerant" or late-tillering stage.

Phenoxy herbicides injured and killed rice roots, but nitrogen stimulated growth of new roots. If nitrogen stimulated roots within 5 days of the herbicide application, the new roots compensated for those injured by the herbicides during a time when the rice plants could utilize nitrogen efficiently. However, root stimulation by nitrogen 15 days after herbicide treatment occurred after the rice plants could utilize nitrogen effectively.

Controlling Aquatic Weeds
With New Experimental Herbicides

Control of aquatic weeds with potassium azide[5]

Ducksalad, redstem and waterhyssop are troublesome aquatic weeds in rice that cannot be controlled selectively during the early growing season (before rice is 4 or 5 weeks old) with propanil or phenoxy herbicides. Seeds of these weeds germinate as soon as rice fields are flooded; therefore, they compete more with water-seeded than with dry-seeded rice. However, since the advent of propanil to control grass weeds, aquatic weeds have become more troublesome in dry-seeded rice. Where propanil is used to control grasses, nitrogen, which stimulates growth of aquatic weeds and enhances their competition with rice, is applied early in the growing season. Draining, followed by thor-

[5]Potassium azide is very poisonous to man and animals. Also it can combine with copper and lead compounds to form a violent explosive. It should be handled only by competent, trained personnel even in research.

ough field drying, and the delayed application of nitrogen, help control aquatic weeds, but are not always effective. New effective herbicides, which can be applied during the early growing season, are needed.

In experiments in the Southern rice
2 area, potassium azide, at 3 or 4 pounds per acre was applied into the flood 15 to 20 days after seeding rice in water. Many weeds less than 2 inches tall, such as ducksalad, waterhyssop, redstem, spikerush, and fimbristylis, were controlled without injury to the rice. However, waterhyssop and spikerush were less susceptible than the others. Rice yields were increased when potassium azide was used to control weeds.

Potassium azide persisted in the flooded soil for about 2 weeks after treatment. Hence, good stands of rice were required to prevent aquatic weeds from re-infesting rice after the herbicide dissipated. Potassium azide did not injure seedling rice growing in a favorable environment. but it injured rice seedlings growing in an adverse environment. Rice growing on calcareous or alkaline soil[3] during periods of cool temperatures was especially susceptible. Drill-seeded rice appeared more susceptible than water-seeded rice, and was injured by early postemergence applications of potassium azide. This new herbicide combined with good cultural practices should help control early-season aquatic weeds in rice.

Control of algae

Algae that infest rice fields include filamentous blue-green genera of *Anabaena, Lyngbya,* and *Phormidium,* and filamentous green genera of *Pithophora, Hydrodictyon, Spirogyra,* and *Zygnema.*

Algae develop in colonies in the surface of the soil after germination of spores in or on the soil. Gelatinous material around the algal filaments collects liberated gases in bubbles in the algal colonies. When sufficient gas accumulates, small sections of algae rise to the water surface where they continue to grow. Soon the algal sections unite to form a solid mass on the water. The bottom of the floating layer of algae is a gelatinous mass covered with soil, but the surface dries to a tough film upon exposure to air. Young rice plants are pulled down into the water or mud by the algae, and rice stands are reduced. Even if plants are not pulled down, new leaves and tillers cannot penetrate the algae. Plants sometimes decay when they are in contact with the algae, probably from infestation by fungi and bacteria in the algal growth.

Table 4. Common, chemical, and trade[1] names of herbicides[2] and insecticides.

Common name or designation	Trade Name	Chemical name
aldrin		1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo, exo-5,8-dimethanonaphthalene
B-60	Brestan 60	triphenyl tin acetate
carbaryl	Sevin	1-naphthyl N-methylcarbamate
CIPC	Chloro IPC	isopropyl N-(3-chlorophenyl) carbamate
CP-97	CP-31497	paratestrory butylphenyl-2-cyanovinylsulfone
D-63	Sindone	1-1-dimethyl-4,6-diisopropyl-5(7)-indanyl ethyl ketone
D-97	Sindone B	1,1,4-trimethyl-6-isopropyl-5(7)-indanyl ethyl ketone
DDT		1,1,1-trichloro-2,2-bis(chlorophenyl)ethane
dieldrin		1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, exo-5,8-dimethanonaphthalene
endrin		1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethanonapthalene
KN_3	Kazide	potassium azide
MCPA		2-methyl-4-chlorophenoxyacetic acid
methyl parathion		0,0-dimethyl-0-p-nitrophenyl phosphorothioate
molinate	Ordram	S-ethyl hexahydro-1 H-azepine-1-carbothioate
0-93	OCS-21693	methyl-2,3,5,6-tetrachloro-N-methoxy-N-methylterephthalamate
parathion		0,0-diethyl-0-p-nitrophenyl phosphorothioate
propanil	Rogue/Stam	3',4'-dichloropropionanilide
silvex		2-(2,4,5-trichlorophenoxy)propionic acid
2,4-D		2,4-dichlorophenoxyacetic acid
2,4,5-T		2,4,5-trichlorophenoxyacetic acid

[1]Mention or omission of any chemical by trade name implies neither endorsement nor criticism by either the U.S. Department of Agriculture or the Arkansas Agricultural Experiment Station. Trade names are given solely for purposes of chemical identification.

[2]Of the herbicides discussed in this report only propanil, molinate, 2,4-D, 2,4,5-T, MCPA, and silvex are registered for use on rice in the United States as of April 1, 1967.

Development of algae is usually rather rapid and varies with soil, water, and environmental conditions. Algae are generally most prevalent on heavy clay soils, but can be a problem on silt loams. High soil phosphorus and nitrogen levels augment algae development; broadcast preplanting applications of these elements stimulate algae. Temperatures of the water and air, combined with light intensity, probably influence algal development more than anything else. Blue-green algae usually occur in abundance only during warm months when temperatures are 85 to 100 F, and when light intensity is high, as during periods of clear skies. High mineral content in the water also stimulates algae.

Although cultural methods such as dry-seeding, draining, rotations, and proper fertilizer management are the predominate practices used for control of algae, certain experimental herbicides control algae effectively. The herbicides, CP-97 at 3 to 6 pounds per acre and B-60 at 1½ to 4 pounds per acre, applied into the flood between formation and flotation of algal colonies, controlled blue-green and green algae without injuring rice. These herbicides failed to control other aquatic, grass, broadleaf, and sedge weeds

Table 5. Rice acreage treated with propanil and rough rice yields in the United States, 1959-66.

Year	Rice acreage treated with propanil[1]	Per acre yield of rough rice[2]
	percent	pounds
1959	0	3,380
1960	0	3,420
1961	1	3,410
1962	15	3,730
1963	50	3,970
1964	60	4,100
1965	75	4,270
1966	80	4,350

[1]*Estimates based on reports by Agricultural Extension Services in rice producing states and by chemical companies that manufacture propanil.*

[2]*Yields for 1959-65 taken from U.S. Dept. Agr. Agricultural Statistics, 1965; yield for 1966 is from U.S. Dept. Agr. FR 2-66, 1966*

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RICE WEED CONTROL IN TAIWAN

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Rice is one of the most important crops grown in Taiwan. It is the staple food of the local populace and it has by far the largest acreage among all crops. Of the 889, 563 hectares of cultivated land in Taiwan, about 60.34% or 536,772 hectares are used for the cultivation of rice. The total planted area of rice in 1966 was 788,635 hectares, producing 2,379,661 M. T. of brown rice. Of the total production, 1,103,426 M. T. of brown rice were produced in the first or spring crop with planted area of 339,745 hectares and the second or fall crop produced 1,276,235 M. T. of brown rice with 448,890 hectares of land.

The total rice production in Taiwan has been increasing at an annual rate of more than 50,000 M. T. of brown rice during the past several years. This remarkable achievement can be largely attributed to the increase in the unit area yield of rice which is one of the highest in the world. According to the FAO Production Year Book (1965 Edition), Taiwan produced 3,894 kg of paddy rice per hectare which was only second to Japan (5,150 kg/ha) among main rice producing countries in Asia. Since Taiwan produces two crops of rice a year, it is more reasonable to count the unit area yield to 7,788 kg/ha. It means that, in a sense, Taiwan has a greater unit area production per year than Spain, the highest yielding country in the world producing 6,210 kg/ha in 1965. The high unit area production of rice in Taiwan is due to many interrelated factors such as the improvement of irrigation, the increased use of chemical fertilizers, the development of better varieties and adoption of improved cultural practices. Of course, an effective weed control program in rice has also contributed greatly to the higher unit area production. The purpose of this paper is to introduce cultural methods used to control weeds in rice and to discuss possibilities on the use of herbicides in paddy fields of Taiwan.

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MOST COMMON WEEDS IN PADDY FIELDS

An island-wide survey of the distribution of weeds on the cultivated land in western Taiwan was made in 1961 under the sponsorship of the Joint Commission on Rural Reconstruction. The results of the survey show that there are 108 species, belonging to 68 genera, and 37 families in paddy fields. Among them, a total of 92 species, belonging to 59 genera, 31 families were found in the first or spring crop season whereas 73 species, belonging to 40 genera, 25 families were found in the second or fall crop season. The most serious weeds which cause losses in rice include: *Monochoria vaginalis* (L.) Presel., *Echinochloa crusgalli* (L.) Beauv., *Cyperus difformis* L., *Lindernia cordifolia* Merr., *Eleocharis acicularis* L., *Dopatorium junceum* Hamilt., *Masilea quadrifolia* L., *Fimbristylis miliacea* Vahl., and *Rotala indica* (Willd.) Koehne.

Most weeds in paddy fields of Taiwan are of hydro- and hygrophytic types which usually occur in spring and summer seasons, and they are largely of annual weeds propagating exclusively from seeds except *Marsilea quadrifolia* and a few others which are of perennial weeds propagating not only from seeds but also from vegetative organs such as rhizome, bulb and stolon. The kinds and distribution of weeds differ with districts depending upon the natural environmental conditions such as climate and soils as well as artificial environmental conditions such as cultural practices and cropping system. Rice yield will decrease markedly if paddy fields are left unweeded. It was observed that non-weeded plots showed yield reductions of 19.3% in comparison with hand-weeded plots in the second crop of 1964 at Chiayi Agricultural Experiment Station.

CULTURAL PRACTICES USED TO CONTROL WEEDS IN PADDY FIELDS

Up to the present time, weeds in paddy fields of Taiwan are controlled entirely by cultural practices and herbicides are used in paddy fields only for experimental purposes, (see Figures 1 to 5). Major cultural practices commonly employed for weed control in paddy fields are summarized below:

Figure 1. The field is usually tilled immediately after harvest of the previous crop by water-buffalo-drawn plows.

Figure 2. After two or three plowings and harrowings, the land is leveled.

Figure 3. Up to the present time, hand weeding is still the most popular means of rice weed control in Taiwan.

Figure 4. When the soil surface is too hard to do hand weeding, a small hand-operated rotary paddy cultivator is used.

Figure 5. Herbicides may become an effective means of rice weed control in Taiwan in the near future.

Use of clean rice seeds

Weeds mixed with rice seeds are the primary source of weed infestation in the nursery and in the paddy field. In order to reduce this damage, seed farms are required to be maintained weed free and certified seeds with satisfactory purity approved by the certifying agency are recommended for farmers in their planting.

Rotation with upland crops

In single-cropping fields, rice is usually rotated with other upland crops like sweet potato, peanut, soybean, and others. Wheat and tobacco can also be grown after the second crop of rice and vegetables, like melons are grown between the first and the second crops of rice in double-cropping fields. By growing upland crops in paddy fields, the infestation of certain hydro- and hygrophytic weeds can be reduced.

Good preparation of nursery and paddy field

The field is usually tilled immediately after the harvest of the previous crop to kill weeds grown on the soil surface by plowing them under the ground. Two or three plowings are usually made prior to seeding or transplanting to reduce weed infestation. The remaining weed plants are also removed from the field before sowing or transplanting.

Weeding and roguing in the nursery

Seedbeds are frequently weeded during the nursery stage. Emphasis is placed on the eradication of barnyardgrass, Bakanae, and off-type seedlings. To make weeding and roguing easy in the nursery, the seedbed is prepared in strips with a width of 1.2 meter in any convenient length, and a 30-cm ditch is also made between the two seedbeds.

Weeding in the paddy field

In Taiwan, weeding in the paddy field is customarily accompanied with intertillage, even though it has long been proved that the effect of a combined practice of "intertillage and weeding" is largely that of weeding and the effect of intertillage per se is quite negligible. Farmers usually practice weeding and intertillage 3 to 4 times in the first crop and 2 to 3 times in the second crop during the growing period of rice. The first weeding and intertillage is done at about 15 days after transplanting in the first crop and 10 days in the second crop, then it is carried out once every 10 and 7 days in the first and the second crops of rice, respectively. The time-to-weed one hectare of paddy field once is estimated to be about 100 man-hours or 10 work-days.

Weeding and intertillage is usually done by hand except in Southern Taiwan where it is done by the use of feet. In case the soil surface is too hard to do weeding and intertillage by hand, a small hand operated rotary paddy cultivator is some times used. Water is drained one day before weeding and top-dressing of fertilizers is generally made on the day of weeding and intertillage.

Roguing in the paddy field

It has been shown that one or two barnyardgrass plants grown with three rice seedlings in a hill will reduce rice yield by 55.4% and 67.6%, respectively, if the barnyardgrass is pulled out at 50 days after transplanting. In order to reduce damage caused by barnyardgrass mix-planted with rice seedlings in a hill, farmers are urged to inspect their paddy fields frequently to pull out all the barnyardgrass as soon as possible. It is also desirable to clean off-type rice out of the paddy field.

Water management in the paddy field

Weed competition with rice is generally more serious during the early stage of rice growth when the rice plant is still small and sufficient space is available for weed infestation. Thus, it is necessary to keep water in the field at a depth of about 3 cm during the first 20 to 30 days after the transplanting to prevent the emergence of weeds. Weed problems are particularly serious in the area where the so called "Rotational Irrigation" is practiced simply because continuous flooding of fields in the early stage of rice growth is not available. After the maximum tillering stage when the open space between rows and hills can be covered by rice leaves, control of weeds by water flooding is no longer needed.

HERBICIDES RECOMMENDED FOR COMMERCIAL USE

The Department of Agriculture and Forestry of the Taiwan Provincial Government has recommended one and four herbicides for controlling weeds in the nursery and in the paddy field, respectively, based on the experimental results obtained at various agricultural experiment stations. Experimental results indicated that Glenbar formulated in 12% emulsifiable concentrate can provide good control of barnyardgrass and other weeds not only in the nursery but also in the paddy field, when applied at the rate of 12 to 15 liters per hectare. It is sprayed on the seedbed right after the sowing in the nursery; whereas in the paddy field, it is sprayed at 4 to 5 and 3 to 4 days after transplanting in the first and the second crops, respectively. The effect of Glenbar has been shown to last as long as 30 days after its application.

TOK formulated in 5% granule can be applied only in the paddy field. It is broadcast on the paddy field by hand at the rate of 30 kilograms per hectare at 5 to 7 and 3 to 5 days after transplanting in the first and the second crops, respectively. Water should be kept in the field at the depth of 3 cm when TOK application is made and the field should remain flooded for at least 3 days to improve the effect of the chemical. TOK can control most of the important weeds in the paddy field except *Cyperus difformis* L. and *Marsilea quadrifolia* L.

Casoron in 50% wettable powder formulation is also recommended for use only in the field. It is sprayed at the rate of 2 kilograms per hectare at 5 to 7 and 3 to 5 days after transplanting in the first and the second crops, respectively. The field should have shallow water of about 3 cm in depth when Casoron application is made and the field should be flooded for 2 to 3 days after its application. Casoron does not control large weeds and *Marsilea quadrifolia* L. PCP and Pamcon in 25% and 14.6% granular formulations, respectively, applied at the rate of 30 kilograms per hectare are also effective in controlling weeds in the paddy field. For these two chemicals, continuous flooding of the field for at least 10 days is necessary.

Propanil which has been intensively studied in Taiwan for the past few years fails to appear on the list of recommended herbicides presumably due to its unstable performance in the second crop of rice when monsoon climate prevails and also to the occurrence of rice injury when propanil interacts with insecticides such as organic phosphate chemicals.

Cost of weeding by hand and by chemical

It is estimated that to obtain good weed control for one hectare of paddy field by hand weeding, 400 man-hours or 40 work-days are needed in the first crop and 200 man-hours or 30 work-days in the second one. Since the current labor cost for hand weeding is about NT$ 25 or US$ 0.625 per man-day, it costs nearly NT$ 1,000 or US$ 25 and NT$ 750 or US$ 18.75 per hectare by hand weeding in the first and the second crops, respectively. Meanwhile, current price figures indicate that the costs of herbicides recommended for commercial use in the paddy field are estimated to range from NT$ 820 or US$ 20.50 per hectare for Casoron to NT$ 900 or US$ 22.50 per hectare for TOK. It appears that chemical weed control is not necessarily more expensive than hand weeding. However, labor required for hand weeding is mostly supplied by family members of the farmer and paid labor is quite limited. As cost of production for transplanted rice in Taiwan is already higher than in other crops, rice farmers may be unwilling to further increase their costs of production by accepting chemical weed control. This is the main reason why all paddy fields in Taiwan are still controlled by cultural methods even though chemicals for controlling weeds are already available. If the costs of chemical weed control can be reduced to less than NT$ 400 or US$ 10 per hectare, chances of acceptance by rice farmers seem great. It appears practical that the first and the second hand weedings that usually require more labor because of severe weed infestations, are to be replaced by one application of certain chemicals which is to be followed by one hand weeding to take care of the weeds spared by the chemical.

SUMMARY

Weed problems in transplanted rice in Taiwan are similar to those of the other tropical countries. Although considerable amounts of time have been spent in screening herbicides for use in rice, weeding in paddy fields is still done largely by hand in Taiwan. Since the majority of rice farmers own only small farms with sufficient family labor, there is no urgent necessity to rely on chemicals for weed control in paddy fields. At the same time, most chemicals are more or less toxic to rice plants and farmers are reluctant to use chemicals at the expense of reducing unit area production of paddy rice. However, chemical weed control undoubtedly will be accepted by rice farmers if materials that are excellent in controlling weeds, low toxicity to rice, cheap and simple in application are available. In view of the rapid progress in industrial development Taiwan has witnessed in recent years, the supply of farm labor is bound to decrease in the coming days, and the demand for chemicals to control weeds in rice will increase in proportion to the decrease in the supply of farm labor. More studies are therefore necessary in Taiwan to screen more herbicides for possible use and to develop new chemical-cultural methods of controlling weeds in transplanted rice.

CHANGES IN ASIAN PLANTATION AGRICULTURE AND THE USE OF 'GRAMOXONE'

G. A. Watson[1]

Plantation agriculture in Asia is passing through a period of considerable change. Spurred on the one hand by the need to provide employment for growing populations and raise national incomes, large areas of jungle are being brought into plantation cultivation mainly in Government subsidised development schemes. On the other hand, in some countries, the need to avoid complete reliance on the major crop, rubber, is resulting in significant acreages of rubber being replaced with the currently more profitable oil palm. In all situations the need to produce quality crops at a price competitive with other sources, and particularly with synthetic materials, is forcing the authorities concerned to adopt the most efficient methods of management.

Perhaps this is seen most clearly in West Malaysia, where it is estimated that over the years 1959 - 1970 estate acreage of rubber will fall slightly from 1,950,000 acres to 1,910,000 acres while the acreage in small-holdings will rise from 1,841,000 acres to 2,536,000 acres (Rubber Research Institute, Malaya, 1961). Over the same period, consequent on the use of high yielding material, total rubber production will increase by some 50%.

Concurrently with these changes in rubber cultivation the West Malaysian planting industry, public and private, has raised its acreage of oil palm from approximately 130,000 acres in 1960 to 250,000 acres in 1966, and expects to reach the 400,000 acre mark by 1970. On a smaller scale these changes are paralleled by events in Sabah and Sarawak, while in Indonesia a major rehabilitation of the 4,500,000 acre rubber industry cannot be long delayed. In Thailand the Government has already instituted a rehabilitation programme for its one million acre rubber industry and, in India, where indigenous rubber production is particularly valuable in saving foreign exchange, new planting developments are taking place in the Andaman Islands.

As far as rubber is concerned these developments are taking place in the shadow of rising production of synthetic rubber and a falling price. In 1960 the mean Singapore price for natural rubber was M $1.08 and this has fallen steadily, bedevilled by stockpile releases, to 56 cents in 1966, little more than the cost of production of the less efficient plantations. In other crops the story is similar: palm oil producers must compete with low cost production in Africa and with other vegetable oils including soya bean oil, a crop that can be completely mechanised and with consequently low labor requirements, the abaca of the Philippines must compete with synthetic fibers while the sugar cane industry faces overproduction and the imposition of production quotas.

To keep vigorously in business all these plantation industries must cut their costs to the bone and maintenance of the plantation itself comes under close scrutiny. For optimum economy the crop plant needs to have a high yield capacity, and to be grown under conditions conductive to optimum growth and yield; a reasonable soil, appropriate fertilisers and the application of any necessary pesticide program should ensure good growth, while proper weed control will eliminate excessive competition for water and nutrients by other plants.

WEED CONTROL AND MANAGEMENT

It can be said correctly that in some territories, but by no means all, the cheapest method of weed control is still by hand. To accept blindly this simple conclusion would be, however, to ignore a number of important management problems. Hand weeding often causes soil compaction, erosion and plant damage, but there are problems extending beyond immediate agronomic matters. On estates hand labor involves hidden costs, with housing, health, education and maternity welfare often the responsibility of the estate; in certain areas labor may be difficult to hold at the time of paddy planting, often the time of maximum weed growth; in Ceylon tea plantations the laborer will prefer to undertake the better paid and more congenial group activity of plucking rather than solitary weeding, while in Malaya the young man leaving Estate school feels he can do better than earn his living by scraping weeds from the surface of the soil. Over and above these points are the generally increasing cost of labor and the relatively decreasing cost of weed killing chemicals (Barlow and Ng. 1966).

Faced with this combination of economic and management problems there has been a move away from the use of large gangs of hand weeders to the employment of small teams of men equipped with knapsack sprayers and herbicides appropriate to the problem in hand. Men permanently engaged on this work can be regarded as having a particular skill deserving of higher pay and prestige than the hand weeder; he can operate faster and more efficiently than the hand weeder and will be a permanent feature of the plantation industry. On estates he may be on the permanent estate staff or be in the employ of a weeding contractor; in Government development schemes he is almost certain to be employed by a contractor until such time as a resident labor force is established. With the permanent need for weed control that exists in these territories one can envisage such contracting teams developing considerable expertise in the type of chemical and equipment to be used for any particular situation, but such development is as yet only in the early stages.

THE REPLACEMENT OF SODIUM ARSENITE

The changing pattern of Asian plantation agriculture is also extending to herbicide usage in the field. What is appropriate for rubber may not be so for oil palm which, for instance, is so sensitive to growth regulators as to prohibit their use in this crop. The greatest change in herbicide usage is, however, likely to come about by the eventual disappearance from use of sodium arsenite.

Sodium arsenite has been the cheapest, most generally effective herbicide used

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in the past with some 8,000 tons per annum being imported into Malaysia alone for use largely in the rubber and oil palm plantations. It is, however, very toxic, a constant liability in use either because of contamination of drinking water, the death of cattle grazing on sprayed vegetation, inducement of severe dermatitis in the sprayer operators, or because of damage to the crop plant. Because of these various hazards the Malaysian Government and plantation industry have been actively developing cheap and effective alternatives to sodium arsenite, and consequent on the progress achieved (Rubber Research Institute, Malaya, 1966) the Government now proposes to bar the chemical completely from use as from March, 1969. This will necessitate all estates and weeding contractors becoming familiar with the use of alternative chemicals among which, and of major importance, is 'Gramoxone'.

First introduced into Malaysia in 1961 'Gramoxone' has received widespread acceptance in the rubber and oil palm industries and is now used at the rate of several hundred thousand litres per annum in that territory. Advantages in its favor over other replacements for sodium arsenite are several. Its great activity means that only a small bulk of material needs to be taken into the field, and that only low volumes of water are required for its application, down to 10 gallons/acre with normal equipment, facts that reduce its cost of application and are of particular importance in difficult terrain. Its safety to the bark of young trees, and inactivation in the soil, mean that even with unskilled labor no harm can come to the crop plant, while its speed of action ensures immediate elimination of weed competition with the crop.

A property of major importance is the rainfastness of 'Gramoxone'. When sprayed onto plants the paraquat ion is immediately absorbed onto the leaf surface and rapidly moves into the plant (Brian, 1967). Even if light rain is falling at the time of spraying a good degree of effectiveness will be obtained, while during the monsoons less than 2 hours need elapse between spraying and rain for the full herbicidal effect to be obtained.

With this combination of properties 'Gramoxone' is a valuable chemical wherever weed control is required. It has, for instance, been adopted on a large scale in the tea plantations of Ceylon and India, where it has been shown that a team of three men, each equipped with a knapsack sprayer and using 'Gramoxone', can chemically weed an area twice or three times as large as that covered when using traditional hoeing or slashing. This releases 3 to 6 men for other work, a great advantage in the peak plucking period. In Malaysian rubber estates current trials in young rubber are showing that the use of 'Gramoxone' weeding methods requires only one quarter of the labor required for hand weeding, and may open the way to low cost plantings. Elsewhere the chemical is being used in the pepper plantations of Sarawak and is likely to find acceptance in the Hawaiian and Philippine sugar plantations. In sugar cane it has been observed that residuals give incomplete weed control by leaving certain resistant species unchecked and often control is so brief that a contact herbicidal spray is required to clean up the area before cane closure. In these circum-

TABLE 1 Generalized recommendations for 'Gramoxone' [1] usage in Asian plantation crops

Weeds	Crop and situation	Rates of application/acre [3]
Mixed grasses	All crops; particularly effective where some shade is present.	1 - 2 pints 'Gramoxone', depending on population density.
Grasses with *Paspalum conjugatum* dominant	All crops, particularly where weed growth is vigorous in absence of shade.	1 pint 'Weedazol' TL, [2] followed 4 weeks later by 1 - 2 pints 'Gramoxone'.
Grasses with *P. commersonii*, *Digitaria* spp. dominant		2 - 4 lbs. dalapon followed 4 weeks later by 1 - 2 pints 'Gramoxone'.
Grasses mixed with broadleaved weeds; cover plants including *Pueraria phaseoloides*	All crops except oil palm.	1 - 2 pints 'Gramoxone' with 0.5 pint 2,4–D amine[4]
Mikania cordata	All crops, including oil palm.	2 pints 'Gramoxone' in 10 gallons water.
Imperata cylindrica	All crops in light-medium shade.	2 pints 'Gramoxone' in 40 gallons water, followed at monthly intervals by spot spraying with 1 pint 'Gramoxone' in 20 gallons.
	Sheet 'lalang' in the open	Either as above or: 6 - 8 lbs. dalapon in 80 gallons water, followed 4 weeks later with 2 pints 'Gramoxone' in 40 gallons water.

[1]'Gramoxone' contains paraquat and is the registered Trade Name of Plant Protection Ltd., a subsidiary of Imperial Chemical Industries Ltd.

[2]'Weedazol' TL contains aminotriazole and is the registered Trade Name of Amchem Products Inc.

[3]In 20 gallons water per acre, except where otherwise stated.

[4]Containing 6 lbs. a.e./U.S. gallon.

...ances 'Gramoxone' has been found to be ...ry effective and preferable to weed oils, sprayed at 1 - 2 pints/acre between the rows. 'Gramoxone' contact on young cane can cause severe apparent damage, but provided spraying is done before the six-leaf stage the plant recovers completely; Gosnell (1964) has in fact shown that despite initial damage an application of 6 pints/acre of 'Gramoxone' gave eventually better yield than did hand weeded plots. In older cane, just before closure, the brown stem sheaf will prevent damage to the cane by 'Gramoxone'.

THE CONTINUING DEVELOPMENT OF 'GRAMOXONE'

Naturally since its introduction the use of 'Gramoxone' has undergone changes. In Malaysian plantations it was found that repeated use of 'Gramoxone' led to the development of infestations of *Paspalum conjugatum*. The answer to this problem proved to be the sequential application of 'Gramoxone' following 'Weedazol' TL and, in the case of other grasses, of dalapon (Table 1). In work against lalang *(Imperata cylindrica)* the use of 'Gramoxone' on its own has in the past proved to be rather expensive, but applied in sequence following 6 - 8 lbs./acre of dalapon it has been found to give effective control at a lower cost than the conventional application of 15 - 20 lbs/acre dalapon.

In the developing oil palm plantations of Malaysia the creeping *Mikania cordata* is a widespread problem: unable to use the normally recommended 2,4-D, 'Gramoxone' applied at 2 pints/acre in 10 gallons of water has, however, proved an efficient and safe alternative. In many situations involving mixtures of grasses with broad-leaved weeds, the overall efficiency of 'Gramoxone' spraying has been improved by applying the chemical in mixture with 2,4-D or MCPA. The mixture of 'Gramoxone' with MCPA is likely to prove of particular value in sugar cane as a pre-and post-emergence spray, the 'Gramoxone' eliminating existing vegetation and the MCPA providing some residual activity at a low cost.

Current recommendations for the use of 'Gramoxone' are given in Table 1. At the same time a continuous programme of development of 'Gramoxone' goes on, with effectiveness of the chemical being improved by the use of new wetting systems and other adjuvants. Like the spraying team, 'Gramoxone' is likely to prove a permanent feature of the plantation scene.

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WEED CONTROL IN WHEAT AND BARLEY

Arnold P. Appleby[1]

The outlook for weed control in wheat and barley is changing rapidly. New varieties and new management practices are expanding the possibilities of these crops in two ways: (1) geographical expansion and (2) higher yields. As an example of geographical expansion, Rockefeller teams in Mexico, Guatemala, and Colombia have developed wheat varieties that are well adapted to tropical and sub-tropical areas. New wheat varieties are being developed in many other countries such as Pakistan and India. Although wheat is often considered a temperate crop, it is rapidly becoming a major crop in many tropical areas.

Yields of these two crops, especially wheat, are increasing very rapidly. In the Pacific Northwest area of the United States yields of over 12,000 kilograms per hectare have been obtained. Yields of 6,000 to 8,000 kilograms per hectare are common. This means that some old ideas of economics in regard to weed control in wheat are no longer true. Ten years ago an investment of $2.00 to $3.00 per hectare would have been considered maximum for weed control in many areas. Now growers are spending up to $12.00 to $16.00 per hectare for weed control in wheat. A grower cannot afford to pay a high price for herbicides to obtain a 30% yield increase when his crop normally yields 1,000 kilograms per hectare. However, an entirely different situation exists when he can obtain a 30% yield increase of a wheat variety that normally yields 6,000 to 8,000 kilograms per hectare.

A considerable number of herbicides have been used for weed control in wheat and barley. I will briefly discuss some of the more important compounds and some new herbicides that appear promising for this purpose.

Herbicides used for broadleaf control include a series of phenoxy herbicides, dicamba (2-methoxy-3,6-dichlorobenzoic acid) bromoxynil (3,5-dibromo-4-hydroxy benzonitrile), diuron (3(3,4-dichlorophenyl)-1,1-dimethylurea), linuron (3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea), and GS 14260 (2-*tert* butylamino-4-ethylamino-6-methylthio-*s*-trizaine). Compounds used for grass control include diuron, linuron, GS 14260, diallate (S-2,3-dichloroallyl-N-N-diisopropylthiolcarbamate), triallate (S-2,3,3-trichloroallyl-N, N-diisopropylthiolcarbamate), and barban (4-chloro-2-butynyl *m*-chlorocarbanilate).

The phenoxy herbicides are still the most widely used compounds for broadleaf weed control in small grains. This class of herbicides includes 2,4-D, MCPA, 2,4,5-T, mecoprop(MCPP), dichlorprop (2,4-DP), silvex (2,4,5-TP) and other miscellaneous phenoxys. Stage of growth of the grain plants is important in determining correct time of application of the phenoxy herbicides. In spring grains, the seedlings plants are quite sensitive and may be easily killed up to the three-leaf stage of growth. From the three-

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leaf to the five-leaf stage, the head or ear primordia are developing. Applications of phenoxys during this time may result in a considerable amount of deformity in the head and severe reductions in yield. The safest time of application on spring grains is from the five-leaf stage to the onset of jointing. The timing requirements in winter grains are somewhat different since the development of the plant depends on certain temperature conditions which may vary from one year to the next. In general, winter grains are quite sensitive during the seedling stage and reach a rather tolerant condition after they have become fully tillered. The optimum time to spray is after the grain is fully tillered but before the jointing stage. Applications after jointing (when stem nodes appear above the soil level) and through the heading and flowering stages can result in severe reductions in yield. The plants again become resistant at about the soft-dough stage of the grain.

Several forms of phenoxy herbicides have been used for weed control in grain crops. These include the water soluble amine, the high volatile esters, the low volatile esters, and the newer oil-soluble amines. In most cases the phenoxy herbicides offer the most economical approach to broadleaf control in cereal crops. However, in many areas the encroachment of weeds which are resistant to phenoxy herbicides or the proximity of desirable plants susceptible to drift of the phenoxy compounds has necessitated the use of other types of herbicides.

Dicamba is an example of a herbicide that controls many 2,4-D resistant weeds, such as *Polygonum* spp., *Rumex* spp., *Agrostemma* spp., *Lamium* spp., etc. However, since it is not effective on several species which are susceptible to phenoxy herbicides, such as *Brassica*, it is often used in combination with a phenoxy herbicide. The combination has been very successful in many areas. Since each herbicide controls different weed species, the combination has resulted in broad spectrum broadleaf control.

Bromoxynil controls a large number of annual broadleaf weed species and has a wide margin of safety on grain crops even in the seedling stage. This is particularly helpful when early germinating weeds are competing severely with the grain but when the grain is too small to be sprayed with phenoxy type materials. Bromoxynil is primarily a contact herbicide and must be applied while the weeds are still small. It is relatively ineffective on large weeds or on perennial weeds.

Diuron, linuron, and GS 14260 are all soil-active herbicides that control a wide variety of annual broadleaf weeds as well as many annual grasses. They can be applied pre-emergence to the weeds, therefore effectively eliminating any competition during the life cycle of the grain crop. Diuron and linuron have been used primarily in winter grains but promising results have also been obtained from their use on spring grains, although spring grains have less tolerance to these materials.

Diallate, triallate, and barban have been used primarily for wild oat control. Diallate and triallate are volatile materials which must be incorporated into the soil immediately after application prior to planting to the grain. Barban is most effective when it is applied post-emergence to wild oats in the two-leaf stage.

Several promising compounds and practices have not been discussed. For example, the use of paraquat for preparing a seedbed chemically rather than mechanically has a great deal of merit and is being studied intensively in the U. S. and in Europe. Time does not permit a discussion of such new practices and compounds. By the next meeting of this group perhaps many of these techniques and herbicides will be in large scale commercial use.

SUMMARY

In summary, there are some thoughts that I would particularly like to leave with you today: (1) Weed control in wheat and barley is big business in the world. Companies are searching for new herbicides for use in these crops and are competing for these markets. (2) The phenoxy herbicides have been useful in the past and are still very widely used for weed control in wheat and barley. However, other compounds are now available that are effective on species that phenoxys fail to control. Many of these new compounds also overcome the drift hazard that the phenoxy herbicides present. (3) The economics of weed control in grain crops is changing rapidly. More and more growers are realizing that if they can spend $5.00 and receive back $30.00 to $40.00 in increased production, they have indeed made a good investment. The possibility of much higher yielding grain crops now makes it much more feasible to invest a larger amount for weed control. This will undoubtedly be true in many other crops in the future.

WEED CONTROL IN CORN: EFFECTIVENESS OF SOME HERBICIDES APPLIED SINGLY AND IN COMBINATION

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2-chloro-4-ethylamino-6-isopropylamino-s-triazine (atrazine) is at present probably that most suitable herbicide for pre-emergence weed control in corn. Since any chemical used as a herbicide has its limitation with regard to the weeds that it can control, the continued use of atrazine may lead to the rapid multiplication of weed species tolerant to this herbicide. There are known cases of such a phenomenon, e.g. the continued use of diuron in sugar cane areas has brought the problem of species tolerant to this herbicide; such as *Erecthites hieracifolia* in Hawaii and *Plantago lanceolata* in Mauritius. This difficulty can be solved by a mixture of diuron and atrazine, since these two weed species are susceptible to the latter herbicide. Thus two of the possible ways to obviate such a problem: 1) the continued evaluation of other herbicides which may be applied singly in "rotation" with atrazine, and 2) the use of these other herbicides in combination with atrazine. The use of other herbicides "in rotation" with atrazine should minimize the rapid multiplication of tolerant species. In mixing herbicides the objective is to broaden the spectrum of weed control without endangering crop safety. Suppose that herbicides A and B were applied separately on a weed population made up of 20 weed species. If 15 species were found susceptible only to B; theoretically a mixture of A and B will result in the control of all species.

The experiments reported here are part of a study undertaken to evaluate "newer" herbicides applied singly and in combination.

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MATERIALS AND METHODS

Two experiments are reported. Experiment No. 1 was conducted during the wet season of 1966 (June to September) and Experiment No. 2 in the dry season of 1966-67 (October 1966 to January 1967).

In the first experiment Philippine Hybrid Id x Carribean Yellow Flint was planted in plots measuring 2.25 x 3 m. at a plant population of about 60,000 per ha. UPCA Var. 1 was utilized in the second experiment. The corn was planted in 4 x 4 m. plots also at a population of about 60,000 per ha. In each experiment 90 Kg/Ha N was applied; ½ of the amount at planting and the other half about a month after planting.

The treatments are outlined in Tables 2 and 3. Each treatment was replicated four times in a randomized complete block design. The chemical nature of the herbicides applied may be seen in Table 1.

Table 1. Chemical nature of herbicides used in the study.

1. Atrazine (At) – 2-chloro-4-ethylamino-6-isopropylamino-s-triazine.
2. CP-31393 (CP) – Ramrod; N-isopropyl-alpha-chloroacetamide
3. Amiben (Am) – 3-amino-2,5-dichloro-benzoic acid
4. UC-22463 (UC) – 3,4 plus 2,3-dichloro-benzyl methylcarbamate
5. Treflan (Tn) – trifluoro-2,6-dinitro-N, N-dipropyl-p-toluidine
6. Glenbar (Glen) – thiomethylester of 2,3, 5,6-tetrachloro-4-carbomethoxy benzoic acid
7. Afalon – 3-(4-dichlorophenyl)-1-methoxy-1-methylurea

Table 2. The effect of six herbicides applied singly and in combination on weed population 30 days after planting and on corn yield, Experiment No. 1.

Treatment[1] (Kg/Ha of herbicide)	Number of weeds (Ave. of 4 reps) Weed Groups				Yield, Kg/Ha
	Grasses	Sedges	Broadleaved	Total	
Weeded	–	–	–	–	4780
Unweeded	43.2	41.0	3.2	87.4	3039
At – 3	2.7	11.0	0	13.7	3751
At – 2	4.2	21.0	0	25.2	3732
CP – 4	6.0	30.2	2.0	38.2	3143
At + CP (2 + 1)	5.0	18.5	. 0	23.5	3737
At + CP (2 + 2)	5.7	7.5	0	13.2	4040
At + CP (2 + 4)	2.0	23.7	0.2	25.9	3436
Am – 2	6.5	35.0	2.2	43.7	3055
AM – 4	0.2	32.2	0.7	33.1	2006
At + Am (2 + 1)	4.0	9.7	0	13.7	3948
At + Am (2 + 2)	2.5	20.2	0	22.7	3377
At + Am (2 + 4)	3.0	17.0	0.2	20.2	3265
UC – 4	8.5	19.5	2.5	30.5	3367
At + UC (2 + 1)	2.7	40.0	0.2	42.9	4142
At + UC (2 + 2)	8.7	39.0	2.0	49.7	4010
At + UC (2 + 4)	5.0	13.5	0.2	18.7	3522
Tn – 1	17.2	33.5	2.7	53.4	3876
Tn – 2	21.7	21.5	1.5	44.7	2804
At + Tn (2 + 1)	9.2	17.7	1.0	27.9	3879
At + Tn (2 + 2)	7.7	25.7	0	33.4	3704
Glen – 2	9.7	37.0	2.0	48.7	3313
Glen – 3	13.7	32.7	3.0	49.4	3670
At + Glen (2 + 2)	6.2	18.5	0.2	24.9	3878

[1]All treatments applied 2 days after planting.

RESULTS AND DISCUSSION

Experiment 1. Wet Season, 1966

The more abundant weed species present in the experimental area arranged in a descending order of predominance were: *Eleusine indica; Cyperus rotundus, Rottboellia exaltata, Ipomoea triloba* and *Portulaca oleracea.*

Table 2 shows the effects of the herbicide treatments on the weeds and on corn yield.

Except for Treflan applied singly, all other herbicide treatments gave very satisfactory control of the grass weed species. It should be pointed out however that even the relatively unsatisfactory Treflan treatments caused about 50 per cent reduction in grass weed population.

The response of *Cyperus rotundus* (nutgrass) to the treatments presents an interesting case. While we do not consider nutgrass a very serious weed problem in corn, its response to some of the herbicide treatments illustrate one of the advantages that could be obtained from the use of herbicide mixtures. None of the herbicides used singly gave a very satisfactory control of this weed species; however when Atrazine plus Amiben (2 + 1 KG/Ha) or Atrazine plus Ramrod (2 + 2 Kg/Ha) was used nutgrass population was immensely reduced. Apparently as far as this species is concerned a mixture of Atrazine plus Amiben or Ramrod is much more effective than any of these herbicides applied alone. For instance at 30 days after planting the nutgrass population in the unweeded plots was 41 per cent 50 x 50 cm. Atrazine at 2 Kg/Ha reduced nutgrass population by 48 per cent while 2 Kg/Ha Amiben caused a reduction in nutgrass population of only 15 per cent. On the other hand a mixture of Atrazine and Amiben (2 + 1) reduced the population of this weed species by 76 per cent. The apparent loss of effectiveness on nutgrass when a higher concentration of either Amiben or Ramrod was mixed with Atrazine can not be fully explained. It is pertinent to mention however that other workers have found that in mixing herbicides, unless the right proportion of the components of the mixture is used, no benefit would be derived from such a mixture.

In the experiment the number of dicot weeds was not sufficient for this group of weed species to be considered a big problem.

The weeds reduced corn yield by about 36 per cent (4780 Kg/Ha for weeded plots and 3039 Kg/Ha for unweeded plots). The highest yield obtained from a herbicide treated plot (Atrazine and UC-22643 (2 + 1 Kg/Ha) was 4142 Kg/Ha; this is about 87 per cent of the yield from the weeded check. The other herbicide treatments in this category are Atrazine plus UC-22643 (2 + 2 Kg/Ha; Atrazine plus Ramrod (2 + Kg/Ha); and Atrazine plus Amiben (2 + 1 Kg/Ha). The yield from these better treatments were 84, 84 and 82 per cent of the yield from weeded plots, respectively. It is interesting to note that these better treatments were mixtures of Atrazine with other herbicides. The yield from the "standard treatment" of Atrazine (3 Kg/Ha) was 78 per cent of the yield from the weeded plots.

Experiment 2. Dry season, 1966-67

The predominant weed species in the order of their prevalence were *R. Exaltata, E. indica, Amaranthus spinosus, I. triloba* and *C. rotundus.*

Table 3 shows the effects of the herbicide treatments on the weeds and on corn yield.

The yield from the handweeded and unweeded plots were 4144 and 2153 Kg/Ha respectively or a reduction in yield due to weeds or about 47 per cent. The yield from plots given the standard herbicide treatment (Atrazine - 3.4 Kg/Ha) was 3215 Kg/Ha which is 77 per cent of that obtained from the handweeded plots.

Afalon (1.1 Kg/Ha) applied at 30 days after planting resulted in a very satisfactory control of grasses and broadleaved weeds. The yield from Afalon treated plots was 89 per cent of the handweeded plots and about 12 per cent greater than that from Atrazine (3.4 Kg/Ha) treated plots.

Treflan at 1.1 Kg/Ha also gave satisfactory control of the weeds; the yield from Treflan-treated plots was comparable to the yield from the standard Atrazine-treated plots.

The better herbicide combinations observed were Atrazine + Ramrod (2.2 + 2.2 Kg/Ha) and Atrazine + Glenbar (2.2 + 2.2 Kg/Ha). Weed counts at 30 days after planting showed that the combination of Atrazine and Glenbar reduced the same by 78 per cent. The yields obtained from these treatments were 76 and 81 per cent of the yield from handweeded plots respectively. These combinations have consistently showed good results during the last two seasons.

Atrazine plus UC-22463 at the two rates used can sufficiently control grass and broadleaved weeds. However, in the experiment the yields from these combinations were much lower than that from 3.4 Kg/Ha of Atrazine. The Atrazine-UC22463 combination seems to perform better during a wet season crop.

The weed species present at harvest were mostly grasses. With the exception of the unweeded plots and those sprayed with 1.1 Kg/Ha of Afalon, the grass weed species present at harvest was *R. exaltata.* While the weed population was less in herbicide treated

Table 3. The effects of the herbicide treatments on the weeds and yield of corn, Experiment No. 2.

TREATMENT	No. per 50 x 50 cm[1]				Wt. per 50 x 50 cm (gm)[2]				Yield Kg/Ha
	S[3]	G[4]	B[5]	Total	S	G	B	Total	
Weeded	-	-	-	-	-	-	-	-	4144
Unweeded	33.5	29.5	13.0	76.0	1.0	40.2	35.2	76.4	2183
Atrazine-3	18.5	18.2	0	36.7	0.5	69.5	0	70.0	3215
Atrazine-2	17.2	17.0	0	34.2	5.7	71.7	0.5	77.9	2843
Ramrod-4	30.2	16.2	3.7	50.1	1.2	47.2	6.5	54.9	2553
At+Ram (2 + 2)	26.2	7.7	0	33.9	3.2	53.0	0	56.2	3173
Glenbar - 3	27.2	13.7	2.7	43.6	2.0	46.2	9.0	57.2	2729
At + Glen (2 + 2)	9.5	7.0	0	16.5	3.0	27.2	0	30.2	3387
Treflan - 1	20.7	2.0	1.2	23.9	2.7	11.5	15.5	29.7	3175
At + Tref (2 + 1)	18.2	1.7	0	19.9	4.0	37.8	0	41.8	3183
UC-22463 -1	27.2	12.5	4.7	44.4	2.0	43.5	11.7	57.2	3149
At + UC (2 + 1)	13.7	5.0	0	18.7	3.2	38.0	0.5	41.7	2937
At + UC (2 + 2)	17.7	3.7	0	21.4	7.0	32.5	1.2	40.7	2714
Amiben - 2	14.2	8.7	3.2	26.1	0.5	67.7	10.7	78.9	2682
At + Am (2 + 1)	20.2	11.2	0	31.4	1.5	55.2	0	56.7	2560
Afalon - 1 (Post)	38.5	30.7	10.0	79.2	3.5	16.2	0	19.7	3618

[1] Taken 30 days after planting
[2] Taken 2 days before harvesting
[3] S - Sedges
[4] G - Grasses
[5] B - Broadleaves

plots, the surviving weeds developed into more vigorous plants. This may be the reason why the good treatments failed to equal the yield from handweeded plots.

SUMMARY

1. The effectiveness of Atrazine, Amiben, Glenbar, Ramrod, Treflan, UC-22463 and Afalon applied singly was studied. The effectiveness of the other six herbicides in combination with Atrazine was also tested.

2. Afalon (1.1 Kg/Ha) as a directed postemergence spray applied at about a month after planting proved a very promising herbicide treatment for corn.

3. The combination of Atrazine + Ramrod (2.2 + 2.2 Kg/Ha) and Atrazine + Glenbar (2.2 + 2.2 Kg/Ha) have consistently shown good results for two seasons.

4. Yield from plots treated with 1 Kg/Ha Treflan was for two seasons comparable to that from plots sprayed with 3 Kg/Ha Atrazine.

HERBICIDES FOR SUGARCANE IN HAWAII: A STUDY OF VARIABILITY

H. W. Hilton[1]

Since about 1940 the Hawaiian sugar industry has been committed to weed control entirely by chemical means. The reasons for using chemical herbicides rather than mechanical cultivation or hand hoeing are: labor economics, rocky, hilly land where cultivation is difficult, large-estate year-round farming where aircraft spraying is feasible, a wide variety of constantly germinating seed and perennial species for which mechanical means would give only short-term control, a permeable soil not requiring frequent disking, and a system of deep ditches and furrows in the irrigated fields, making them inaccessible to machines Since we irrigate about 50% of the total land in sugarcane which receives less than 75 inches of annual rainfall, and since fertilization of sugarcane is heavy, all the land under cultivation is subject to continuous, rapid weed growth.

We rely on the airplane (irrigated areas), the tractor (unirrigated areas), and the pressurized hand knapsack (all areas) for distribution of the chemical herbicides in the fields, ditches, roads, and other treated areas. There are about 225,000 acres of sugarcane in Hawaii, of which half, or 112,000 acres, is harvested each year. Chemical weed control of the treated fields from planting or ratooning to close-in (lay-by) averages about $45-50 per acre, for a total annual cost of some $6,000,000, about 6% of the value of the raw sugar crop. Almost two-thirds of this cost is for chemicals, 30% is labor cost and 5-10% machinery and equipment. Chemical cost has increased considerably in the past 10-15 years as a result of shifts to newer herbicides and practices, but at substantial savings of labor, so the total cost has remained stable or actually decreased. The rising cost and scarcity of labor, particularly for carrying the hand knapsacks, and the ceiling on sugar prices force us to continue to search for improved methods and practices of weed control. Our efforts have been mainly in improvements in mechanical application, improved pre-emergence seedling control, and improved control or eradication of individual perennial species which require repeated treatment. Ideally we would like to be assured of complete weed control with one application, instead of the average of three treatments at present, but there are no herbicides capable of this degree of control, and field conditions make ideal control difficult even for the best herbicides.

Chemical weed control presents a complex study in variability: variability of performance between herbicides, variability of the performance of a single herbicide from place to place and time to time, and variability in crop tolerance between individual varieties and between locations where one or more varieties are planted. Most of this discussion will be concerned with the subject of variability, for several reasons. One: it exists, and we must understand it to cope with it. Two: it is useless to discuss chemical weed control without considering the range and magnitude of variability. Three: it is useless to try to adapt the practices of one area to another without a thorough knowledge of the conditions in both areas. For example, there are very good reasons why the weed control practices in sugarcane in Hawaii, Louisiana, and Florida are totally different. It is my personal belief that not much of what I can tell you about our practices will be of direct value in your own area, but we can hope to consider the variable factors which influence either the practice or the chemical herbicide used.

Economics must be the first consideration, including chemicals, labor, equipment, and overhead costs for alternate practices. Unfortunately, trial and error is required to find the preferred practice for a given part of the world. Many sugarcane planters prefer to use cultivation, with chemicals as an occasional supplement for special problems. A switch to total chemical control requires a complete consideration of the effects of crop culture without cultivation – economic and agronomic. Crop injury from chemicals, or from cultivation, may reduce yields if the injury is severe enough or near harvest age. This risk may make certain practices preferable whatever the cost of alternatives.

The type of desired weed control is a factor not easy to assess. We all recognize that weeds compete for sunlight, water, space, and nutrient with the crop. Some weeds, like vines and rhizomatous perennials, may compete so seriously as to cause total crop loss if allowed to grow, yet others are only esthetically unwelcome. We in Hawaii have come to expect near-total control, or bare ground, until the crop shades out the soil at 4-6 months, preventing further growth. We do not try to control nutsedge (*Cyperus spp.*) in most areas because the cost of doing so exceeds the advantages.

Two approaches to chemical weed control are used for sugarcane, with some overlapping: soil applications to prevent seedling growth, and foliar treatment of emerged weeds. We use predominantly soil treatment (with foliar treatment only where necessary), Louisiana has used mainly foliar herbicides, and Florida finds cultivation preferable in their even, flat fields. The long-residual "broad-spectrum" soil-applied herbicides – diuron, atrazine, and ametryne – provide (for us) maximum control of the greatest number of weeds in their most

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vulnerable seedling stages. The best for irrigated areas in Hawaii is ametryne while diuron is superior for unirrigated high-rainfall fields.

WEED CONTROL PERFORMANCE FACTORS

Weed control performance of the soil-applied (pre-emergence) herbicides is extremely variable under our conditions even though the practice has become widely accepted. Over a period of years we have identified the following factors which contribute to the variable performance:

1. Soils differ in adsorptive capacity, reversibly adsorbing 70-95% of the applied herbicide in topsoils, and 5-50% in subsoils. Adsorption is due mainly to soil organic matter, and to carbon from pre-harvest burning of the crop leaves. The high adsorption prevents leaching and crop injury from diuron, except in exposed subsoils or sandy soil, but requires greater rates of chemical treatment to maintain an active level lethal to germinating seed.

2. Water and soils are interdependent. Optimum weed control requires that the top few inches of soil remain moist to keep the herbicide active. Such conditions are not common even with irrigation, although our poorest control is in unirrigated areas during drought. Water-table levels may be important factors for some locations.

3. Each chemical has a performance pattern characteristic of the chemical, the soils, available water, and weed species. The differences in Hawaii are considerable with 10 to 200 inches of annual rainfall, a variety of soil types related to geologic age and climate, and the often-curious patterns of weed populations with water, soil, or temperature (due to elevations from sea level to 3,000 feet).

4. No chemical is completely non-selective to all species. We find such a wide mixture of grasses and broadleaves in most fields that the chemicals with broadest control of all species do the best job. It may also be of interest that combination of two or more herbicides are generally of little value here for pre-emergence use, unless *both* are of the non-selective type and unless each component is present at an amount more or less optimum if it were used alone. For example, diuron + ametryne at (2 + 2) lb/acre does not compare well with 4 lb/acre of each used alone. However, combinations at (3 + 3) lb/acre and especially (4 + 4) lb/acre perform increasingly well compared with 6 or 8 lb/acre of the single product.

5. Cultural practices vary widely, and to a large extent determine the field conditions for weed growth or herbicide performance. Such things as plowing depth, cultivation, harrowing or planting, replant in ratoon fields, irrigation method and timing, fertilization, and many others, influence the timing of weed control operations, the soil structure, disturbance of soil, of seed in the soil, and of any pre-emergence chemical treatment, the conservation of soil moisture, and the vigor of the crop and of the weed population.

6. Human and mechanical errors in application constitute yet another source of variability. Part of this error complex can be recognized and minimized – such as uneven aircraft applications, overlapping patterns, wind drift, nozzle erosion or plugging, etc., but a part will remain the variation from unknown causes. Training and supervision of spraying operations are often critical factors even after all other conditions are considered; their lack may result in failure of the herbicide or, worse, injury to the crop.

One further variable is the crop variety. Each variety of sugarcane shows a difference in tolerance to most herbicides. These differences are basic to the variety, as they occur when the plants are grown in nutrient solution as well as in the field. Susceptible varieties absorb the herbicide at a faster rate, perhaps differences in transpiration rate are responsible for the observed effects. In the field we must also recognize the effects of water, soil, climate, nutrient status, and cultural practices on the differential response of sugarcane varieties to herbicides. These effects are superimposed on the inherent varietal susceptibility.

BASIC PHILOSOPHY

Our basic philosophy in chemical herbicide testing, as an approach to dealing with the problems of variability, is to try to select those materials or practices which most readily fit the largest numbers of plantation situations. Individual variations from this basis can be taken care of cooperatively with the individual plantations. Selection of improved herbicides or practices is based on replicated small plot observation experiments repeated as often as possible in as many varied locations as possible. Evaluation of both chemical performance and crop tolerance is made in comparison with standard herbicides–diuron, atrazine, and ametryne–included in each test. Without the standards the tests are worthless.

For our conditions, and I emphasize only for our conditions, the triazine herbicides such as atrazine, ametryne, atratone, GS-14254, and others provide the maximum pre-emergence weed control combined with maximum crop tolerance. The substituted ureas, diuron and monuron, also have value in certain locations, particularly for unirrigated sugarcane. Although there are varietal differences, sugarcane is more tolerant of the triazines than of any other potent herbicide, because it can metabolize the triazines to non-toxic compounds. In contrast, the substituted uracils, pyridines, and even ureas do not show the same degree of selectivity, and crop injury occurs with considerable frequency from the first two groups.

SUGARCANE INJURY

Sugarcane injury from herbicides may appear as a leaf burn, general leaf chlorosis or chlorosis of margins and tip, stalk deformity (usually epinasty), or stunting with or without other visible symptoms. Unless injury is severe, the effects are usually reversible, that is, the crop recovers in appearance and growth. Permanent shortening of one or more nodes may result; whether yields of sugar are decreased will depend on severity of injury, on the time from injury to harvest, and on the general field conditions for vigorous growth and rapid recovery. We have not seen any instances of yield losses from normal use of chemical herbicides.

Chemicals and practices for post-emergence weed control tend, at the present, to consist of treatments of diuron + dalapon [(5 + 5) lb/acre + 0.25% surfactant] or of ametryne (5 lb/acre), which control perennial species, any escapes or regrowth from the pre-emergence treatment, and at the same time leave a soil-residual material for any seed germination occurring after the treatment. Some use, though decreasing, is still made of pentachlorophenol (PCP) in oil, 2,4-D, and STCA, and minor amounts of 2,4,5-T and silvex are used for special species. Of the newer experimental products only picloram (Tordon) shows possibility for control of some special vine and brush species.

Much more could be said of conditions peculiar to sugarcane culture in Hawaii. However, it should be evident that I believe there is no substitute in another country or set of conditions for a program of trial and error covering the range of variable conditions and possible methods of weed control. There is no key to instant success. We have evolved a system of chemical weed control which works remarkable well, but it must go on evolving as new materials appear and as economics change. A survey of the plantation programs will all show systems in transition, containing practices from the past as well as the present, and with considerable interest in possible future changes.

Many improvements could be made in herbicides and practices. For example, we should be able to kill seed in soil before it germinates, or kill perennials as they appear through the soil, or control nutsedge, or kill perennials with just one treatment. As yet no one has a better answer than chemical weed control for those places where labor cost is high or where mechanical means cannot be used for some reason.

Weed control by chemical means depends on a complex set of interrelated factors, all of which must be at least partially understood before commercial practice will be successful. We try, in our program in Hawaii, to maintain close contact and cooperation with the plantation personnel, to plan an intelligent testing program with their problems as a guide, and to evaluate the program in terms of the greatest benefit to the sugar industry. The purpose of this paper was to try to show that we can benefit our own industry most by understanding the variability within it; we can benefit yours only by comparison with your own conditions.

PRELIMINARY STUDY ON CHEMICAL WEED CONTROL IN SUGAR CANE INTERCROPPED WITH SOYBEANS AND PEANUTS[1]

Sheng Y. Peng and Wen B. Sze[2]

For intensive utilization of arable land as a result of population increase, intercropping systems of sugar cane with a short-season bean crop or a cereal have prevailed in recent years. India is another country where similar cultivation systems are known to exist, but no chemical weed control programs of intercropping were found in the literature. Although the programs of applying diuron or atrazine in combination with 2,4-D sodium salt as pre-emergence treatments on sugar can have been widely-used for years in this region, a program suitable to an intercropping system is still not developed. There are some interesting problems when chemical methods of weed control are tried for an intercropping system in which two morphologically different crops are grown in association. The differential tolerance of crop plants to herbicides and their varied biological competition against weeds can be mentioned as examples.

To test the tolerance of individual plants of sugar cane, soybeans and peanuts to a range of new herbicides, an experiment with pot-cultured plants was reported by the authors (1). The possible alternatives for chemical weeding in such a complex system of cane were also pre-discussed in another article (2). This paper presents a discussion of results of a preliminary investigation (initiated in August of 1965) on the possible use of chemical herbicides to control weeds in two intercropping systems of sugar cane with soybeans and peanuts. For acquiring more information, an ordinary non-intercropped system of cane was also placed within the frame work of the experimental design.

RESULTS

An experiment was conducted to evaluate fourteen chemical herbicides (2,4-D, diuron, Hyvar X, linuron, paraquat, dalapon, amiben, fenac, MCPA, Butyrac, TOK E-25, afalon, sesone, and atrazine) in combination with times of application (broadcast pre-emergence, directed post-emergence, and hand-weeding) and certain cultivation types of sugar cane. The cultivation types of cane (9 in total) were formed according to whether cane was interplanted with peanuts or soybeans or none at all in different planting times. A total of 28 treatments was thus formed and arranged in field layout according to a randomized complete block design (see Tables 1 and 2).

In the group of directed post-emergence applications (DPA), all treatments showed excellent results of weed control compared with hand-weeding and the standard pre-emergence application with diuron and 2,4-D (at 2 + 2 kg/ha). All treatments showed no adverse effects on cane plants but rendered severe damage to intercrops except the treatment in which the compounds paraquat, dalapon and 2,4-D (at 2L + 5kg + 2kg per hectare) were used to treat cane in DPA and soybeans were intersowed later. Due to the late planting time, seed yield of soybeans in this treatment was not obtained though the bean plants grew normally.

In the group of pre-emergence hand-applications in which different chemicals were used to treat either cane (in furrows) or intercrops (on ridges), the associations of fenac-amiben (3kg + 3L per ha), afalon-TOK E-25 (3kg + 10L per ha), and atrazine-sesone (3 + 3.5 kg/ha) were good for cane intercropped with peanuts or soybeans and comparably good yields of these intercrops were produced. But due to their mild herbicidal activity the efficacy of weed control was only as good as hand-weeding. The association of linuron-MCPA was also useful for cane-peanut but not for cane-soybean intercropping systems.

TOK E-25 could be also used in a broadcast pre-emergence application (at 20 L/ha) to treat sugar cane intercropped with peanuts. This treatment not only provided good weed control but also resulted in the highest yield of peanuts.

DISCUSSION

In southern parts of Taiwan where cane is grown for sugar manufacturing, about 80% of the annual 2,000 mm rainfall is concentrated in the months from June through early September. This uneven distribution of rainfall through the year has been a major obstruction to extending chemical weed control programs for cultivating cane. Sometimes a torrential rain shortly after a pre-emergence application of herbicides may wash the chemicals from the field before soil adsorption of the herbicide. Even though mixture of diuron and 2,4-D at 2 + 2 kg/ha for pre-emergence treatment has been recommended for more efficient weed control, cane growers are thus hesitative to use the more expensive but reliable diuron during the rainy season. Instead 2,4-D sodium salt

[1]Completion of this research project is through assistance from the National Council on Science Development, Taiwan, China.

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Table 1. Intercropping types of sugarcane (cane in furrows; peanuts or soybeans on ridges).

Types	31st Aug.	Crops planted in 30th Sept. (1 month later)	16th Nov. (1½ month later)
A	Cane	–	–
B	Peanuts	Cane	–
C	Cane and Peanuts	–	–
D	Cane	Peanuts	–
E	Cane	–	Peanuts
F	Soybeans	Cane	–
G	Cane and Soybeans	–	–
H	Cane	Soybeans	–
I	Cane	–	Soybeans

Table 2. Treatment combinations.

Number	Types of Applications of Herbicides	Intercropping types[1] of cane treated
0	Non-sprayed (hand-weeding 4 times)	A, C, D, G, H
1	Broadcast pre-emergence diuron + 2,4-D (2 + 2 kg/ha)	A, D, H
2	Broadcast pre-emergence 2,4-D (2 kg/ha) and Directed post-emergence Hyvar X + 2,4-D (2 + 2 kg/ha)	A, E, I
3	Broadcast pre-emergence 2,4-D (2 kg/ha) and Directed post-emergence linuron + 2,4-D (3 + 2 kg/ha)	A, E, I
4	Broadcast pre-emergence 2,4-D (2 kg/ha) and Directed post-emergence Gramoxone W + dalapon + 2,4-D (2L + 5kg + 2kg/ha)	A, E, I
5	Band-sprayed, ridges pre-emergence amiben (3 L/ha) furrows pre-emergence fenac (3 kg/ha)	B, F
6	Band-sprayed, ridges post-emergence MCPA (2 L/ha) furrows pre-emergence linuron (3 kg/ha)	B, F
7	Band-sprayed, ridges post-emergence Butyrac (5L/ha) furrows pre-emergence diuron (2 kg/ha)	C, G
8	Band-sprayed, ridges pre-emergence TOK E-25 (10 L/ha) furrows pre-emergence afalon (3 kg/ha)	C, G
9	Band-sprayed, ridges pre-emergence sesone (3.5 kg/ha) furrows pre-emergence atrazine (3 kg/ha)	C, G
10	Broadcast pre-emergence TOK E-25 (20 L/ha)	C

[1]See Table I for description of intercropping combinations.

alone is used widely because of its cheapness. Successful weed control in most cases, therefore, is not obtained due to the limited use of diuron. A new technique of utilizing some herbicides in directed post-emergence applications (DPA) seems promising because of the comparably excellent results of weed control achieved. A sophisticated mixing of various herbicides to perform contact, translocative as well as residual activities in one application or combined applications, is the objective of planning such applications. By using this technique the herbicides can be sprayed onto weeds under cane plants when the monsoon period is just over. Unpredicted loss of expensive herbicides in ordinary pre-emergence applications during the monsoon period can thus be avoided. However, before the DPA method is practiced it is necessary to use a dose of 2,4-D (2kg/ha) as a pre-emergence spray for subduing the onrush of seed-germinated annuals which generally occur after preparation of the fields. An improved method in which a pre-emergence spray of diuron and 2,4-D in 30 cm bands on furrows alone followed by DPA in 90 cm bands on ridges is worthy of mention. By this method the loss of herbicides by washing of unpredicted torrents can be reduced to one-fourth when compared with overall applications with the same mixture of herbicides in a pre-emergence treatment. After furrows have been pre-treated in this way, the DPA on ridges is so facilitated as to reduce the danger of contacting tops of cane seedlings by close sprays. Chemicals as Hyvar-X or paraquat tested in this way may cause severe damage to cane seedlings if they are sprayed indiscriminately. A slight degree of phytotoxicity may be incurred by lower leaves of young cane contacted by fume drifts from the DPA treatment. But in all cases the affected plants soon totally recover. The DPA treatment is therefore useful to serve as a supplementary method for weed control in autumn-planting cane if bad weather has failed the pre-emergence applications. In DPA studies herbicides such as Hyvar-X linuron, paraquat and dalapon, which provide efficient control of most annals did not provide satisfactory control unless 2,4-D was added to the spray mixture. 2,4-D serves to reduce infestation of *Cyperus rotundus* which even heavy dosages of strong soil sterilants as the uracils could not prevent regermination of the deep-seated perennial tubers in the soil.

Four alternative methods of applying herbicides can be used for an intercropping system in which a short-season bean crop or one of the cereals is grown between rows of young established cane. Firstly, the intercrop is drilled on ridges after the residual effect of herbicides that have been sprayed as broadcast pre-emergents for cane have diminished. This method for interplanted peanuts or soybeans has not been successful in Taiwan because residues of diuron are still harmful to germination of these susceptible crops even one month after application. Other mild herbicides as atrazine or afalon may be hopeful and should be tried in the same way to test the hypothesis of this method.

Secondly, two different groups of herbicides can be used in band-applications for either cane or intercrops. Since band-application is separable in this case, time of sowing intercrops relative to cane may be adjusted to find the best association for both crops. This method is more feasible than others because suitable herbicides recommended for special bean crops or cereals to be intersowed are easily found in markets. Phytotoxicity usually on the part of inter-crops can be decreased to the least extent owing to no direct interference from those compounds sprayed on cane. After settling down on ridges the casual fume drifts or perhaps the lateral diffusion in soils from those strong toxicants being band-sprayed on cane could be detrimental to the later growth of inter-crops. Such combinations as fenac-amiben, afalon-TOK E-25 and atrazine-sesone thus are less toxic than linuron-MCPA and diuron-Butyrac when susceptibility of inter-crops is concerned. As revealed by separate observations of percent weed control either on ridges or in furrows, furrow-sprayed linuron and diuron are more toxic than the other chemicals. Therefore, when this method of applying different herbicides as band-sprays is employed for weed control in an intercropping system, a mild pre-emergent for cane should be used.

The third method is to delay sowing of intercrops a length of time after a directed post-emergence application of herbicides has been made for cane. Since a DPA should be made usually 20-30 days after planting cane, the postponement of sowing intercrops would involve problems of photoperiodism. It was shown in the experiment that sowing soybeans one-half month after cane which was later treated by a DPA mixture of paraquat + dalapon + 2,4-D (at 2L + 5kg + 2kg per hectare) showed no adverse effect on bean plants. No harvest of seeds was obtained, however, owing to failure of flowering. This method should be tried again in early-planting cane from the standpoint of efficient weed control.

The fourth alternative is to make a broadcast pre-emergence application with some herbicides for both principal and subsidiary crops planted at the same time. This could be the most convenient way of controlling weeds for an intercropping system if satisfactory herbicides are available. TOK E-25 (at 20 L/ha) seems to fulfill this purpose because it not only produces good weed control but shows the least effect on sugar cane and soybeans.

In an intercropping system of sugar cane, the growth of both crop plants is mutually influenced by biological competition. Herbicidal effect may play a part in the influencing forces if the intercropping system is treated by herbicides for weed control. Although evidence has shown that the combined influence on tillering of cane gradually terminates following harvest of inter-crops and plowing of field ridges, just how much and how far each component of influencing forces would play is not known due to the limitation of experimental evidence. An experiment with a factorial design intended to determine how much and how far such factors as inter-crops, weeds, as well as herbicides could affect the growth of cane plants is underway. It shall serve as a critical trial for a reasonable solution of the problems involved.

SUMMARY

Cane yield was not influenced by any herbicidal effects of all the compounds tested but evidently by the cultivating conditions. The influencing forces (herbicidal effects and biological competition from inter-crops) were found to effect the tillering of cane only during the early five months of cane growing when inter-crops were still in field. Following harvest of inter-crops and plowing of plot ridges, the influence gradually terminated. In the case of plant height of cane, this character showed larger variations among treatments which fluctuated from month to month through a great part of the growing season. It indicated its susceptibility to influence of environments on plots which were difficult to determine with the design of this experiment.

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TRIFLURALIN FOR PRE-EMERGENCE WEED CONTROL IN SUGARCANE

C. Van der Schans[1]

Trifluralin* (a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidein) has proved to be a selective soil incorporated pre-emergence herbicide of exceptional quality. It is registered for use on many crops in the United States and other areas of the world. Plant species found to be tolerant to trifluralin include many of the major crops of the world.

CROPS TOLERANT TO TRIFLURALIN (TREFLAN)

Cotton	Rice (transplant)
Fruit, nut trees	Soybeans
Irish Potatoes (postplant)	Sugar beets (postplant)
Ornamentals	Sugar cane (postplant)
Peanuts (Spanish, bunch)	Vegetables

(A complete list of crop registrations can be found on the current product label). Extensive field research is being conducted at the present time on many other crops to determine the herbicidal efficacy and safety of trifluralin.

Following is a list of weed which are sensitive to trifluralin when it is incorporated into the soil at recommended application rates:

IMPORTANT WEEDS CONTROLLED BY TRIFLURALIN

Treflan

Susceptible Grasses

Common Name	Scientific Names
Barnyardgrass	*Echinochloa crusgalli*
Bluegrass, annual	*Poa annua*
Brachiaria	*Brachiaria* spp
Brome, downy	*Bromus tectorum*
Cheat	*Bromus secalinus*
Crabgrass	*Digitaria* spp
Crowfootgrass	*Dactyloctenium aegyptium*
Foxtail	*Setaria* spp
Goosegrass	*Eleusine indica*
Johnsongrass (from seed)	*Sorghum halepense*
Jungle-rice	*Echinochloa colonum*
Panicum, fall	*Panicum dichotomiflorum*
Panicum, Texas	*Panicum texanum*
Sandbur	*Cenchrus* spp
Shattercane	*Sorghum vulgare*
Sprangletop	*Leptochloa* spp
Stinkgrass	*Eragrostis cilianensis*
Witchgrass	*Panicum capillare*

Susceptible Broadleaves

Carelessweed	*Amaranthus palmeri*
Carpetweed	*Mollugo verticillata*
Chickweed, common	*Stellaria media*
Goosefoot	*Chenopodium* spp
Knotweed	*Polygonum* spp
Kochia	*Kochia scoparia*
Lambsquarters	*Chenopodium album*
Nettle, burning	*Urtica urens*
Pigweed	*Amaranthus* spp
Puncturevine	*Tribulus terrestris*
Purslane	*Portulaca oleracea*
Pusley, Florida	*Richardia scabra*
Thistle, Russian	*Salsola kali*

Trifluralin is recommended at rates of 0.5 to 1 pound of active ingredient per acre (0.5 - 0.9 kilogram/hectare) depending on the soil type. The accumulation of research data on the behavior of trifluralin in different geographical locations has made it possible to establish an application rate to fit the cropping practices in specific areas of the world.

Soil incorporation improves the performance of trifluralin in several ways:

1. An effective concentration of trifluralin throughout the zone of weed seed germination is established.
2. It provides weed control for a longer duration than a surface spray. This is of particular importance for a long season crop such as sugar cane.
3. Less trifluralin is required when it is soil incorporated than when applied as a surface spray.
4. Rainfall or over-head irrigation are not needed to move the herbicide into the soil.

Trifluralin can be incorporated with the tandem disc, the rolling cultivator, and PTO-driven equipment such as rotary tillers. These implements should pulverize large clods and mix the herbicide thoroughly with the soil. The proper tillage depth for incorporation equipment varies with the soil and the tool employed, but a depth of less than two inches may result in erratic weed control. Whenever possible, application and incorporation should be combined in a single operation for maximum effectiveness.

MATERIAL AND METHODS

Trifluralin was evaluated during the 1965-1966 growing seasons for pre-emergence weed control in sugar cane. Additional experiments were established this year to obtain more information about crop tolerance and herbicidal activity. Experiments were conducted in the United States, Australia and Southeast Asia on a wide range of soil types using different varieties and application rates. An emulsifiable concentrate (EC) formulation of trifluralin was applied as a soil incorporated, pre-emergence, preplant or postplant spray to plant cane. On ratoon cane it was applied as a postplant soil incorporated application. The studies included different methods of incorporation which could be adapted to various regions. Either the rolling cultivator or the power-driven rotary tiller was used for soil incorporation.

A similar design was used in all experiments and all treatments were replicated 3-4 times. Plot sizes varied in the different experiments but were approximately 600 sq. ft.

RESULTS

Table 1 presents data from an experiment in which a comparison was made between preplant and postplant applications to plant cane.

This experiment demonstrated that a postplant application of trifluralin was an effective and safe herbicidal treatment for new plantings of sugar cane. Preplant applications resulted in moderate to severe injury to the sugar cane. Reduced weed control with preplant applications may have been due to untreated soil being brought to the surface during the planting operation.

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[1]Field Research Coordinator, Contribution of Eli Lilly and Company, Greenfield Laboratories, Greenfield, Indiana.

*Treflan: the registered trademark for Elanco Products trifluralin.

The data in Table 2 represents the average weed control ratings and crop injury ratings obtained in 11 experiments. Trifluralin was applied in the fall as a postplant soil incorporated treatment at 1, 2, 3 and 4 lb/A to plant cane. In general applications were made on the same day as planting however, some were delayed for as long as 12 days. Application and incorporation were accomplished in a single operation.

These experiments demonstrate that postplant soil incorporated treatments of trifluralin to fall planted sugar cane are effective and safe at rates of 1 to 4 lb/A. There was no apparent injury to the sugar cane as a result of the incorporation apparatus used.

Studies established to determine the effect of trifluralin on ratoon cane substantiate the results obtained with plant cane. Table 3 illustrates the results from two experiments where trifluralin was applied at rates of 1, 2, and 3 lb/A to the third ratoon crop. Crop residues were present in all plots, and some of this material was incorporated into the soil.

Crop trash remaining after harvest did not have a detrimental effect on the thoroughness of incorporation. In one of the experiments it was noted that the incorporation operation stimulated the growth of the cane, and at midseason the sugarcane in the treated plot was 10 to 20 inches taller than cane in the control plots. Weed control was excellent and there was no apparent injury to third year ratoon cane as a result of treatments.

Additional experiments were established to study the effect of trifluralin on the crop vigor and yield of sugarcane. Table 4 is the summary of data obtained form experiments involving plant cane grown in Louisiana and Florida.

Grass and broadleaf weed control was excellent with all rates of trifluralin used in these experiments. The herbicide did not injure seed cane and cane tonnage was higher in the trifluralin treatments than in the control. Sugarcane quality, as determined by percent sucrose and Brix ratings, was not affected by trifluralin.

Experiments involving fall and spring applications were conducted in Louisiana during the 1966-1967 crop seasons. Repeat applications of trifluralin at the recommended rate resulted in commercially acceptable pre-emergence weed control of winter weeds, Johnsongrass seedlings, and summer grasses. These treatments did not reduce the number of plants per acre or result in crop injury.

Table 1. A comparison between preplant and postplant applications of trifluralin.

TREATMENT	Rate		Weed Control Rating[a] Grasses[b]	Broadleaves[c]	Crop Injury Rating[d]
TREFLAN 4 EC	1	PoPI[e]	9.2	7.8	0
	2	PoPI	9.7	8.3	0
	3	PoPI	9.7	8.8	0
TREFLAN 4 EC	1.5	PPI[f]	9.0	5.0	8
	3	PPI	9.9	8.5	6
Control	0		0	0	0

[a]Weed Control Rating 0-10: 0 = zero % control; 10 = 100% control
[b]canarygrass (*Phalaris sp.*), little barley (*Hordeum pusillum* Nutt.)
[c]common chickweed, henbit
[d]Crop Injury Rating 0-10: 0 = no injury; 1-3 - slight; 4-6 = moderate; 7-9 = severe; 10 = death
[e]PoPI - postplant soil incorporation with a power-driven tiller.
[f]PPI - preplant soil incorporation with a power-driven tiller.

Table 2. Trifluralin applied as a postplant soil incorporated herbicide to fall planted sugarcane.

TREATMENT	Rate (Lb/A)	Weed Control Rating[a] Grasses		Broadleaves		Crop Injury Rating[b]
TREFLAN 4 EC	1 PoPI[c]	9.5	(7)[d]	8.8	(10)	0
	2 PoPI	9.9	(7)	9.3	(10)	0
	3 PoPI	9.9	(5)	9.6	(4)	0
	4 PoPI	10.0	(1)	10.0	(1)	0
Control	0	0	(11)	0	(11)	0

[a]Weed Control Rating 0-10: 0 = zero % control; 10 = 100% control
[b]Crop Injury Rating 0-10: 0 = no injury; 1-3 - slight; 4-6 = moderate; 7-9 = severe; 10 = death
[c]PoPi - postplant soil incorporation with a power-driven tiller
[d]Number of experiments in which observations were made

Table 3. Effect of trifluralin on third-year ratoon cane.

TREATMENT	Rate (Lb/A)	Weed Control Rating[a] Grasses[b]	Broadleaves[c]	Crop Injury Rating[d]
TREFLAN 4EC	1 PoPI[e]	9.9	9.3	0
	2 PoPI	9.8	9.4	0
	3 PoPI	10.0	9.5	0
Control	0	0	0	0

[a]Weed Control Rating 0-10: 0 = zero % control; 10 = 100% control
[b]Brachiaria; goosegrass, crabgrass, barnyard grass
[c]Pigweed, clammy groundcherry
[d]Crop Injury Rating: 0-10: 0 = no injury; 1-3 = slight; 4-6 = moderate; 7-9 = severe; 10 = death
[e]PoPI - postplant soil incorporation with a rolling cultivator

CONCLUSIONS

The data presented here have led to the following recommendation for the use of trifluralin in sugarcane. In the United States trifluralin should be applied in the fall or spring to either plant cane or ratoon cane. It should be applied at the recommended rate and soil incorporated as a postplant, pre-emergence herbicide. Trifluralin should not be applied to soils containing more than 10% organic matter. Trifluralin can be applied anytime after planting or ratooning the cane up to the time the young settlings are 6-10 inches tall. Care should be exercised so that the incorporation implements do not damage seed pieces or the established crowns of the ratoon cane.

In areas where cane is planted above the furrow, the seed bed should be firmed or rolled prior to the application and incorporation of trifluralin. When trifluralin is applied to ratoon cane, crop residue should be removed by burning prior to harvest, or by shaving the beds prior to application. The old beds should be tilled to a depth of 2 to 3 inches prior to incorporation to allow adequate mixing of the soil.

Experiments conducted in Australia during 1965-1966 have substantiated the results reported in this paper, and an application for the registration of trifluralin on sugarcane has been submitted to that government. An experimental permit has been applied for in the United States, and large scale field trials should be possible in 1967.

Table 4. Effect of trifluralin on the crop vigor and yield of sugarcane

TREATMENT	Rate (Lb/A)	Yield[a] T/A	Percent Sucrose	Brix Rating[b]
TREFLAN 4EC	1 PoPI[c]	29.8	12.7	22.7
	2 PoPI	29.0	13.4	22.8
	3 PoPI	25.7	---	---
Control	0	21.6	12.7	22.7

[a]Values for Yield and Percent sucrose are data from Experiment JB6-3

[b]Data from experiment LG6-13, refractive index values represent apparent percentage solid matter as determined by an Atago hand refractometer. These values parallel but do not equal sucrose content of cane juice.

[c]PoPI is postplant soil incorporation with a rolling cultivator

SUMMARY

1. These experiments indicate that the control of grasses and broadleaf weeds was excellent with all postplant treatments of trifluralin.
2. Preplant soil incorporated applications caused a reduction in germination, inhibition in growth and moderate to severe injury to the sugarcane.
3. All postplant applications of trifluralin were safe to sugarcane and did not reduce tonnage or percent sucrose.

WEED CONTROL IN TARO

(Colocasia esculenta L. Schott)

D. L. Plucknett, D. F. Saiki, P. S. Motooka[1]

Although taro *(Colocasia esculenta* L. Schott) is one of man's oldest crop plants, little has been done to improve the cultural techniques in growing the crop. Taro, a member of the Aroid family, is grown commercially in Hawaii on a small scale, mostly under submerged conditions in the costal valleys. Most operations are carried out by hand labor, and costs of production are steadily rising. As a result, many farmers are leaving the industry because hand planting and harvesting in paddy culture is difficult and often distasteful.

Over the years considerable interest has been shown in producing taro as a nonallergenic specialty food for babies and persons suffering from gastro-intestinal disorders. In order for an expansion of the industry to occur, however, the crop must be mechanized and modernized, and its culture must be shifted from paddy to either furrow-irrigated or upland conditions. With a shift from paddy to systems such as intermittent flooding or furrow-irrigation, mechanized planters and root harvesters could be adapted for use in taro. Without an adequate weed control method, however, such improvements cannot take place.

Weed control in taro is difficult because of the growth cycle of the crop. Newly planted taro is most susceptible to weed competition during the first three or four months when growth of the foliage is just beginning and when little canopy exists. By the fourth month, the crop grows tall and a heavy leaf canopy develops which shades out weeds. As the crop matures, however, the leaf canopy recedes as successive leaves which arise become smaller, resulting in a more favorable environment for weed growth. The mature stage of the crop is also especially susceptible to severe yield reductions due to weeds since this is the most active starch storage period.

In wetland or paddy conditions weed control is less difficult than in upland conditions because some weed control is afforded

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by flooding. If good weed control in wetland taro can be obtained during the first three months of the crop, a good yield usually will result because shading and flooding suppress weeds for most of the remainder of the crop period. At present, most taro growers employ directed contact oil sprays and hand weeding for weed control.

In upland taro, weed control is a problem throughout the cropping period. Shading becomes less important in suppressing weeds because plant spacings are wider, total growth and resultant canopy are sometimes reduced because of insufficient moisture, and physical methods of weed control such as flooding are not possible. Since mechanical weeding is impractical and labor costs make handweeding uneconomic, it is apparent that herbicides must be employed for upland taro weed control.

Kasasian (1967) has studied chemical weed control in taro. He found pre-emergence applications of ametryne, prometryne, prometone, neburon, amiben, TCA, and dalapon caused no injury, but atrazine, simazine, diuron and fenac caused some injury to taro.

A list of common weeds in taro fields is presented in Table 1. This list is representative for wetland taro, but no list is submitted for upland taro since little is grown in the state. It is safe to say, however, that important weeds in upland taro are those which are troublesome in vegetable fields.

Table 1. Some problem weeds in wetland taro[1].

Pacific azolla, azolla fern (Azolla filiculoides)
bermudagrass, manienie, mahiki (Cynodon dactylon)
junglerice (Echinochloa colonum)
barnyardgrass (Echinochloa crusgalli)
paragrass, panicumgrass, California grass (Brachiaria mutica, syn. Panicum purpurascens)
sour paspalum, Hilo grass (Paspalum conjugatum)
green kyllinga (Cyperus brevifolius)
marsh cyperus (Cyperus javanicus)
twoleaf fimbrystylis, tall fringe-rush (Fimbristylis diphylla)
bulrush (Scirpus sp.)
spreading dayflower, honohono (Commelina diffusa)
arrowhead (Sagittaria sagittaefolia)
egeria, waterweed (Egeria densa, syn. Elodea densa)
waterlettuce (Pistia stratiotes)
waterhyacinth (Eichhornia crassipes)
pickerel weed (Monochoria vaginalis)
tarweed cuphea (Cuphea carthagenensis)
primose willow, kamole (Jussiaea suffruticosa)
parrotfeather (Myriophyllum brasiliense)
Asiatic pennywort (Centella asiatica)
white thunbergia (Thunbergia fragrans)
tropic ageratum (Ageratum conyzoides)
yerba-de-tago, false daisy (Eclipta alba)

[1]Names of weeds are listed according to the standardized list, Weed Society of America (1966).

EXPERIMENTAL RESULTS

Upland Taro Experiments

Herbicides used in the tests on upland taro on Kauai with little or no injury were: benefin, trifluralin, dacthal, sodium azide, potassium azide, bensulide, CIPC, EPTC, atrazine, prometryne, prometone, and ametryne, (Furtick, et. al., 1965).

Results of two experiments are presented in Table 2. These herbicides were applied as directed sprays after transplanting. Trifluralin gives best grass control in upland conditions, but is not effective against most broadleaf weeds. However, trifluralin has given 8 to 10 weeks of weed control in a Hanamaulu silty clay (Humic Latosol) and a Uaoa silty clay loam (Alluvial Soil) when applied after planting as a pre-emergence spray to the weeds. For good control retreatment would be necessary at about 2 month intervals throughout the life of the crop. At Kauai Branch Station, trifluralin applied

Table 2. Herbicide experiments on upland taro. Island of Kauai. 1963.

	Kauai Branch Station, Wailua			Kilauea Sugar Company, Ltd. Kilauea		
Treatment	Rate (a.i.) Kg/ha	crop	weeds	crop	broadleaf weeds	grass weeds
Diphenamid	2.24	1	2	1	2	2
	4.48	1	3.7	1.5	1	1
Trifluralin	1.12	1	4.4	1	4	3
CDAA	4.48	1	3.4	1	3.4	2
CDEC	4.48	1.3	2.7	1	3.4	2.4
	6.73	1	3	1	3.4	2
G 32292	2.24	2	3.7	1	3	2
	4.48	2	4	1.6	4	2
Atrazine	2.24	3.3	4.7	2	3	1.4
	3.36	3.6	5	4	4.4	3.4
CDAA-(granules)	1.12	1	2.4	1	2.7	3
CDEC-(granules)	6.73	1	3.3	1	3.4	2.4

[1]RATING SCALE, AVERAGE OF 4 REPLICATIONS

Crop	Weeds
1. no injury	1. no control
2. slight injury	2. slight control
3. moderate injury	3. moderate control
4. severe injury	4. good control
5. killed	5. killed

Weeds in taro cause most serious losses when plants are small and shading is minimal (note left). At right, propanil was used at 6.72 kg per hectare.

Taro grown in paddy suffers little from weeds after 3 or 4 months when the leaf canopy forms.

In upland taro a combination of polyethylene strip-mulching and pre-emergence herbicides may prove most satisfactory.

Table 3. Yields and weed control ratings of wetland taro herbicide experiment, Kauai Branch Station, 1964[1]

	Herbicide, active ingredient Kg/ha	yield, fresh corms, Metric tons/ha	Weed Control Ratings[2]
Check	0	6.08	1
Propanil	3.36	11.93	4
Ametryne	3.36	11.52	5
Frometryne 80 W	3.36	5.22	5
Prometone 25 E	3.36	16.70	5
TOK-10 G	3.36	17.69	3.6
L.S.D. at 0.05		7.27	

[1]Fertilizer applied per hectare acre preplant; 2.26 metric tons/lime and N 168, P 560, K 224 kilograms. Plots 2.44 x 6.40 m., plants spaced 0.61 m. x 0.61 m., herbicide treatments replicated 3 times. Crop harvested 5/11/65, crop period – 16.5 months.

[2]1=no control, 5=complete control; ratings made 3/9/64.

...arithmically up to 8.9 kilograms per hectare (kg/ha) gave no injury even when sprayed over plants with mature leaves.

Prometryne at 2.24 kg/ha has given excellent weed control for about 3 months when applied as a pre-emergence spray just after transplanting. This rate produces some interveinal chlorosis of the taro leaves, but the chlorosis disappears later in the cropping period. Ametryne at low rates also appears effective for weed control in upland taro. Mulch bed planting of taro with black plastic strips has been used and good weed control has been achieved. The main problem was failure of suckers to emerge because of trapping and shading by the plastic mulch.

Wetland Taro Experiments

In 1964, a herbicide experiment was established at Kauai Branch Station within terraces especially constructed for submerged taro culture. The results of this test are shown in Table 3. Best weed control was given by propanil, ametryne, and prometone.

Propanil is a contact herbicide and is applied over both crop and weeds as a post-emergence treatment. For best results, weed should be allowed to grow to near a 5 cm. height before spraying. The paddy should be drained prior to treatment in order to obtain maximum herbicide coverage, and two or three days should pass before flooding again. If the field must be flooded at time of application, water depth should be adjusted to give maximum exposure of weeds to the contact spray.

Prometone and other pre-emergence herbicides must be applied on the soil surface, so the paddy must be drained prior to treatment. Prometone at 3.36 Kg/ha can be directed around the base of the plants and will give control for 4-5 months even after flooding is resumed.

SUMMARY

Chemical weed control in taro is essential if the industry is to be modernized. Under improved management, existing lowland valleys could be converted from paddy to intermittent flooding or furrow irrigation, thus allowing mechanized planting and harvesting.

Most promising herbicides in lowland taro are: propanil, prometone, ametryne, and TOK. In upland taro trifluralin, prometryne, and ametryne have provided good weed control with little injury to the crop.

Black plastic mulch bed plantings provided good weed control under upland conditions, but emergence of suckers was hampered by shading and trapping by the plastic mulch.

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BIOLOGICAL CONTROL OF WEEDS IN HAWAII

Harry K. Nakao[1]

Approximately 97% of the weeds in Hawaii are exotic and these species have succeeded in attaining that status because the natural ecological balance of the flora was disturbed. And today, weed control is one of the most important cultural practices in Hawaiian agriculture. Weeds are costing the agricultural industries millions of dollars annually in reduced yields and control measures.

The rapid development of new herbicides, most of them specific, has presented the agriculturist today with a wide array of material from which to choose. In addition, there have been extensive improvements in methods of applying herbicides. With the improvements in methods of application, chemical control of weeds is possible in almost all situations. However, in pastures where the return from the land is low, chemical or mechanical control may be uneconomical.

Of Hawaii's total of 4,100,000 acres, about 1¼ million acres are devoted to cattle raising, but much of this is marginal land and in most cases heavily infested by weeds. With low productivity and rising costs, ranchers have long been concerned with the problem of weed control and rely heavily on biological means for an economical and effective solution. It is in this area that

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biological control of weeds has had its most spectacular successes.

The first record of biological control of a weed pest was the work done in 1902 by Perkins and Koebele in Hawaii on the verbenaceous plant, *Lantana camara* var. *aculeata* Moldenke. Introduced into the Hawaiian Islands in 1858 as an ornamental, it escaped cultivation and soon became a serious pest of pasture lands.

The original search for insect enemies of lantana was carried out in Mexico and Central America and 23 species were introduced but only 8 became established: the lantana seed fly, *Ophiomyia lantanae* (Froggatt); the lantana lace bug, *Teleonemia scrupulosa* Stal; the tortricid moth, *Epinotia lantana* Busck; the lantana plume moth, *Platyptilia pusillidactyla* (Walker); the lantana leaf miner, *Cremastobombycia lantanella* Busck; the lantana gall fly, *Eutreta xanthochaeta* Aldrich; the larger lantana butterfly, *Strymon echion* L. and the smaller lantana butterfly, *Strymon bazochi gundlachianus* (Bates). These introductions greatly curtailed the spread but failed to exert sufficient stress to effectively control lantana.

In 1952 the lantana project was reactivated and the search for additional enemies resulted in the successful introduction of six species, bring all parts of the plant under attack.

Since these introductions were made, striking control of this aggressive range weed has been noted. Continuous depredation by the lantana stick caterpillar, *Catabena esula* Druce from California (1955); the lantana leaf tier, *Syngamia haemorrhoidalis* Guenee from Cuba and Florida (1956) and most important, the lantana defoliator caterpillar, *Hypena strigata* Fabricius from Kenya, Africa (1957) has resulted in severe dieback of lantana, particularly in areas with less than 40 inches of rainfall.

The most promising introduction is the destructive stem and root boring lantana cerambycid, *Plagiohammus spinipennis* Thomson. Introduced from Mexico in 1959, it is well established on the island of Hawaii and control lantana in the wetter areas appears promising. Heavy girdling, resulting in dieback and, often, collapse of stems have been observed.

Progress by two leaf-mining beetle, *Octotoma scrabripennis* Guerin-Meneville (1959) and the Brazilian hispid, *Uroplata girardi* Pic (1961) has been very encouraging to date.

Another notable project is the control of *Eupatorium adenophorum* Spreng., commonly known as "pamakani." Pamakani is Hawaiian, meaning wind blown, because of the manner in which the buoyant seeds are disseminated. It is a fast growing tropical American shrub and was first introduced into Hawaii as an ornamental at Ulupalakau, Maui, in 1860. Subsequently, it spread rapidly and thousands of acres of valuable rangeland became overgrown with this pest. Between 1920 and 1948, considerable time and money were spent in mechanical clearing of infested land. H. T. Osborn in 1924 listed insects he found associated with pamakani in preliminary investigations in Mexico and recommended biological control of this range pest in Hawaii but no action was taken at that time.

In 1945 the Eupatorium gall fly, *Procecidochares utilis* Stone was introduced from Mexico. The maturing larvae of this fly causes formation of galls and the resulting damage to the plant reduces the stem and foliar growth and seed production. The repeated attacks finally reduce the vigor of the plant to a point where it dies. Where the fly is abundant, not only are practically all the shoots attacked but are also attacked a number of times during their growth and most of the galls are compound ones.

This stem gall fly established itself readily and within a decade brought about such effective control of pamakani that ranchers consider the problem solved and no longer apply control measures.

A more recent project is the control of tree cactus, *Opuntia megacantha* Salm-Dyck generally known as "panini" in Hawaii. It was introduced from Mexico in 1809 as a forage plant for the arid regions.

By 1930 the ranchers, especially on the island of Hawaii, were alarmed at the rapid spread of cactus which covered the lowlands almost solidly in many areas and was moving into valuable pasture lands at the higher elevations.

Following Australia's early successes, the biological control of this range pest was seriously considered in 1943. However, this was opposed by some ranchers who felt that cactus was an asset in times of droughts and it took years to overcome this opposition.

In 1949 a program to import insect enemies of cactus from California and Texas was initiated. Seven species were introduced but failed to become established.

Learning of the unsuccessful results in Hawaii, the Australian Government recommended the introduction of the cactus moth, *Cactoblastis cactorum* (Berg) (1950) which had produced such excellent results in Queensland. Also recommended were the cactus trunk borer, *Archlagocheirus funestus* Thomson (1951) and the cactus mealybug, *Dactylopius confusus* Cockerell (1950). These species became established readily and the dense stands of cactus in the lowlands have been eradicated in most areas on Hawaii. Control of cactus at the higher elevations, predominantly the white fruited variety which is resistant to attack of the introduced insect enemies, has been somewhat slower.

At about the same time control measures were directed towards a polygonaceous weed, *Emex spinosa* Campd. which was taking over fairly large areas of pastureland on Parker Ranch on the island of Hawaii. This plant is native to the Mediterranean basin and is thought to have been accidentally introduced with grass seeds from Australia. It is a sprawling annual herb producing seeds enclosed in a spiny burr that are spread by grazing animals and to some extent by rain water.

Early attempts at control were temporary measures and included hoeing out as many plants as possible before they produced seeds. Later, in heavily infested areas the ground was plowed and Kikuyu grass planted to suppress the emex.

In 1950, investigations were conducted in Italy and Sicily to study the insects associated with emex. In Sicily, a weevil was found infesting stems of emex but it was also reported attacking beans and therefore was considered an unsafe introduction.

In 1956, after learning that another species of emex, *Emex australis* Steinh. was present in Africa and Australia, the search for insect enemies was continued in South Africa. Exploration in South Africa resulted in the discovery of the stem boring weevil, *Apion antiquum* var. *harcyniae* Hubenthal. Releases were made at Parker Ranch in 1957 and it proved to be a very effective control agent. Within three years, large patches of emex were being killed off and replaced by forage grasses. Ranch agriculturists estimated that as a result of biological control the ranch saved $5,000 annually that would have been expended in labor and material for emex control.

Apion antiquum was also released on Maui and is now well established and exerting considerable stress on emex.

Two other weevils, *Apion violaceum* Gyllenhall from Portugal and *A. neofallax* Warner from North Africa, were introduced in 1962 and if these become established, more effective control of emex in the drier areas is expected.

The most recent accomplishment is the control of puncture vine. There are two species present in Hawaii – the true puncture vine, *Tribulus terrestris* L. and the native nohu, *Tribulus cistoides* L. Both species are similar in appearance. Nohu is native to the warmer parts of the North Pacific and in Hawaii is prevalent along the beaches on the leeward side of the islands. The low spreading growth forms a thick mat, hence the name nohu, which means "carpet weed" in Hawaiian. *Tribulus terrestris* is thought to have been introduced with imported seeds. This species has been reported only from the islands of Kauai and Maui and showed every indication of becoming a serious pest, especially in cultivated areas.

The late Jim Holloway, USDA Entomologist, during his visit to Hawaii in 1962 suggested the introduction of the puncture vine seed weevil, *Microlarinus lareynii* (Jacquelin du Val) and the stem weevil, *Micro-* effective in control of puncture vine in California. Subsequently, the seed weevil was released on Kauai in 1962 and it became established in a short time. Within a year it was effectively destroying 75% of the seed crop.

In 1963, the stem weevil was introduced and in three months, was well established. Within two years all existing growth of puncture vine in West Kauai was destroyed by the work of this weevil; even seedlings were attached and killed back.

Both weevils were released on Oahu and Maui in 1964 and are duplicating the excellent control observed on Kauai. These weevils also attack the native nohu.

It is too early to evaluate the effectiveness of control by these weevils but complete control of puncture vine appears very likely.

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WEED PROBLEMS OF PASTURES AND RANGES IN HAWAII

P. S. Motooka, D. L. Plucknett, D. F. Saiki[1]

Of the agricultural endeavors in the State of Hawaii, the beef and dairy cattle industries rank third in economic importance, second only to sugar and pineapple. More than 304,000 hectares of a total land area of slightly more than 1,640,000 hectares are devoted to pasture. (unpublished data, University of Hawaii).

Despite the salience of this industry in Hawaii, there has been very little work done in pasture and range weed control except for a flurry of activity shortly after the introduction of 2,4-D and 2,4,5-T, and the continuing efforts of the State Department of Agriculture in biological control and noxious weed control.

Presented in this paper are some of the most serious or potentially serious range and pasture weeds of Hawaii and the total management program approach to weed control that is being taken by the Hawaii Agricultural Experiment Station.

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BACKGROUND

In order to appreciate the weed problems of pastures and ranges in Hawaii, two significant points must be acknowledged: first, the Pacific Ocean was an effective barrier to the movement of plants, animals, and men; secondly, several climatic zones exist on each major island.

Isolation of Hawaii

The isolation of the Hawaiian archipelago resulted in colonization by only a few plants so that at the time of Captain Cook's discovery of Hawaii there were only an estimated 1,200 plant species of which over 1,000 were endemic (1).

With the advent of the white man in 1778, the native flora was subjected to a barrage of abuses: land was cleared, timber logged, animals released upon plants that evolved without grazing and very significantly, hundreds of foreign species were introduced. Today in Hawaii, the landscape is composed of over 2,000 exotic plants. Every major weed species was introduced and plants of wide origin are commonly found in a single association.

While it is difficult enough to find an herbicide effective against a range of species, the heterogeniety of Hawaiian plant populations confounds the problem even more.

Vegetation Zones

Although small in area, Hawaii has distinct climatic zones which were recognized by its original Polynesian inhabitants and which were reflected in their system of land division. In this system each chief was awarded a pie-shaped wedge of land that extended from the coase to the mountain top in order that he might have access to the sea for fishing, the lowlands for taro production, the upland slopes for planting sweet potato and the forests for logging timber (3).

Very simply, the climatic zones of Hawaii result from the interaction between the tradewinds and the land masses. On the open Pacific Ocean, rainfall is only about 500 mm per year (5). When moisture-laden tradewinds meet the mountainous islands however, orographic rainfall results from the subsequent upward movement of the air masses. Generally then, rainfall increases with elevation until the point of maximum condensation. Temperature generally decreases with increases in elevation and this also is of significance in plant distribution.

SOME SERIOUS WEEDY PESTS OF PASTURES AND RANGES

In 1967 a survey was conducted among ranchers running 50 or more head to determine their major weed problems. From early returns of questionaires, it is evident that ranchers are eager to help and to receive help in the study and control of weeds. Major weeds listed were as follows:

Guava - *(Psidium guajava L.)*

A shrub which grows into a small tree, guava is probably the most common woody pest in Hawaii. In a 1952 survey, guava was said to cover 90% of all areas on which weed control was practiced (12). It is found on all islands below 760 m elevation where rainfall is at least 760 mm.

Guava was introduced from Central America for its fruit which is used commercially to make jams, jellies and fruit juices. The yellow, pink-fleshed fruit with many hard seeds is eaten by birds and animals, and guava is thus disseminated. This tough woody shrub will sprout readily from roots left after mechanical clearing operations. According to the Department of Agiculture, guava infests 310,000 hectares in this state (2).

Lantana *(Lanatana camara L.)*

Lantana was introduced as an ornamental in 1858 and with the help of birds, now covers 179,000 hectares (2).

This thorny, woody shrub was the first plant subjected to biological weed control, beginning about the turn of the century; nonetheless, it is still considered one of the most serious weeds in Zones B and C_1 - (See Table 1 for zone descriptions).

Hamakua pamakani *(Eupatorium riparium* Regel.)

After guava, Hamakua pamakani is the major complaint of ranchers on the island of Hawaii. It is a low shrub and a prolific producer of wind born seed. Very adaptable, it is found in moist areas of all altitudes up to about 2,140 m and covers 53,500 hectares on Maui and Hawaii, mostly on Hawaii (2).

A larger relative of this weed shrub, pamakani or Maui pamakani *(E. adenophorum* Spreng.) is equally adaptable and is found in similar climate zones as E. riparium. Maui pamakani is found mostly on Molokai (2).

Brazil peppertree *(Schinus terebinthifolius* Raddi).

An ornamental from Brazil, this wooly shrub produces clusters of bright red berries that make attractive Christmas wreaths and dry arrangements, and therefore is called Christmas berry in Hawaii. Thus, people collecting the berries for ornamental uses and birds feeding on them account for the dispersal of the weed. One rancher considers it potentially more noxious than guava. Approximately 42,500 hectares are affected by this plant. It is common in Zones B and C_1 (2).

Hairy fleabane *(Pluchea odorata* (L.) Cass.)

An accidental introduction from tropical America, this large, freely branching shrub is very adaptable and thrives in all areas except the very dry areas and the very high altitudes. It grows as well in marshes and saline soils as on typical agricultural soils.

Kipu-kai Ranch reports that this weed and a close relative, indian fleabane *(Pluchea indica* (L.) Less.) are their most serious weed, for they grow in inaccessible places on mountainsides and produce an inexhaustible supply of windborne seed. Although covering only 20,600 hectares at present (2), this weed threatens to become more widely distributed.

Java plum *(Eugenia cuminii* (L.) Druce). Syn *E. jambolana* Lam.

A tree introduced from Africa for its fruit, Java plum is found on all islands in the low, moist areas and is very common along stream beds. It has proved resistant to several brush and tree herbicides.

Joee *(Stachytarpheta sp.)*

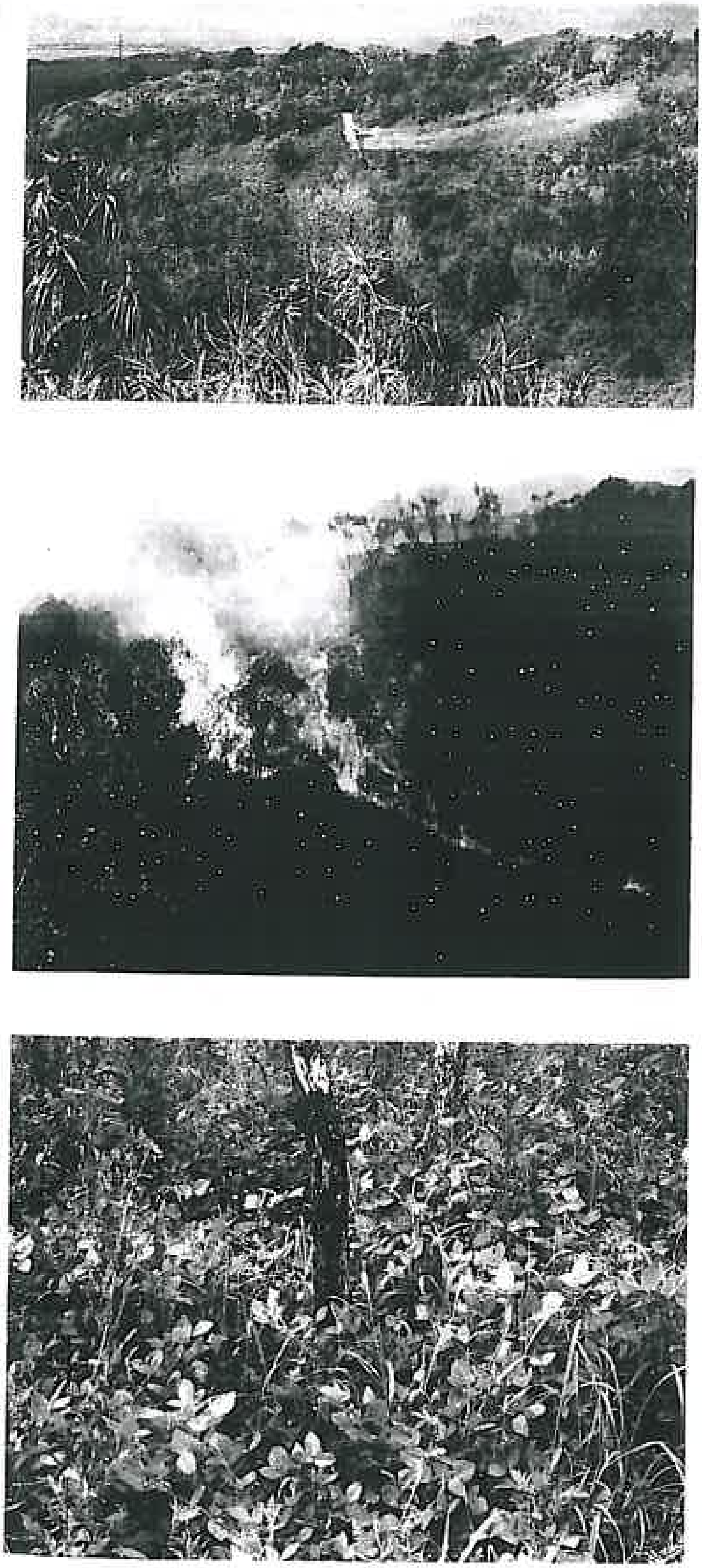
Very similar in appearance and distribution, *S. jamaicensis* (L.) Vahl, and *S. cayennensis* (L. C. Rich) Vahl. are commonly found in the moist areas of the low and middle altitudes. Since their introduction from tropical America, they have spread over 238,000 hectares (2).

Banks melastoma *(Melastoma malabathricum* (L.)

Found only on the island of Hawaii and Kauai, melastoma was introduced as an ornamental in 1909 (6). Although this shrub is reportedly resistant to hormonal herbici-

Table 1. Vegetation zones of Hawaii (13).

Zone	Phase	Approximate Altitude Limits (m)	Approximate Rainfall Limits, (mm)	Natural cover	Land Use
A		300	508	Xerophytic shrub with coastal fringe of trees	Mostly Sugar Cane
B		900	508 - 1,000	Xerophytic shrub with some trees in upper part	Sugar Cane
C	1	750	1,000-1,500	Mixed open forest and shrubs	Sugar Cane & Pineapple
	2	750-1,200		Mixed open forest	Pineapple & Dry range
D	1	450	1,500	Shrub and closed forest	Range, poor grasses
	2	Variable	1,500	Closed forest	Mostly forest
	3	1,200 to less than 2,100		Open forest	Forest water - shed
E	1	1,200-2,100		Open forest and shrub	Dry range – Waste
	2	2,100-3,050	1,300	Mainly upland open shrub	Waste
	3	3,050		No seed-bearing plants	Waste



Conversion of a brush-infested valley to useful pasture in Hawaii. From top, right: aerial application of silvex at 8.96 kg per hectare in split applications; burning the dead vegetation; growth of legumes and grasses after aerial seeding and fertilizer treatments.

des, excellent response to silvex has been obtained, although two or more applications are required for complete kill (8).

A heavy seeder, melastoma is spead rapidly by birds that feed on its fruit. It infests 15,400 hectares of land of which 3,240 is on Kauai.

Other important weedy Melastomaceae found in Hawaii are: *M. decemfidum* Roxb. - Hawaii; *Tibouchina semidecandra* (Schrank and Mart.) Cogn. - Kauai, Hawaii; and *Clidemia hirta* (L.) D. Don - Oahu (11).

Downy Rosemyrtle *(Rhodomyrtus tomentosa* (Ait.)Hassk.)

Originally from Southeast Asia, Rhodomyrtus was introduced to Kauai in 1909 (6), and later on Hawaii. Solid stands of this shrub now cover 2,420 hectares in the Kilohana crater area of Kauai (2). Like melastoma, this plant favors Zones D_1 and D_2 and is spread by birds.

Blackberry *(Rubus penetrans* Bailey)

A rambling spiny shrub, blackberry was introduced at the turn of the century from the continental United States for its fruit. It grows aggressively in the upper altitudes of Zones C and D on the four largest Hawaiian islands. About 17,500 hectares of land, mostly on Hawaii and Kauai, are infested (2)

Firebush *(Myrica faya* Ait.)

Introduced from the Azores by Portuguese immigrants, firebush is a freely branching shrub or tree with small red berries on which birds feed. Found on each of the four major islands, it is a most serious pest in the Hamakua area of the island of Hawaii where it was first introduced. It covers almost 7,300 hectares of the low and middle phases of Zones C and D on that island (2).

Sourgrass *(Trichachne insularis* L.) Nees)

Accidentally introduced from Puerto Rico, sourgrass is a serious pest of the dry areas on Molokai and Oahu. It is found on all islands and infests 33,900 hectares: 20,200 hectares on Molokai and 12,300 hectares on Oahu (2).

Cat's claw *(Caesalpinio sepiaria* Roxb.)

A rambling, thorny leguminous shrub from southeast Asia of recent introduction, this pest is most serious on Hawaii and Kauai. It is found in the low moist areas, Zones C_1 and D_2 (2).

A MANAGEMENT APPROACH TO WEED CONTROL

The most significant contribution that can be made in the problem of pasture and range weed control is in the development of a total management program in which weed control is an integral segment.

Very often, weed control is a treatment of a symptom of a deficiency in management practice, as for instance, where overgrazing results in brush infestation. Under such a condition weed control without controlled grazing is futile. Thus, control of weeds in such a situation merely creates a vacuum which invites reinfestation unless management is improved. On the other hand, maintenance of vigorous forage stands prevents most weed problems in pastures and ranges. By logical extension of this reasoning then, a pasture and range weed control program may be defined as the conversion of weedy vegetation to productive forage stands, although conversion is usually associated only with land severely infested with brush.

Conversion is accomplished by favoring the growth of forages by such practices as fertilization, controlled grazing, reseeding and by suppressing the growth of weed species by any method or combination of methods most effective under a given set of conditions. The following methods might be applies:

Herbicidal Treatment

Efficacy of herbicides depends upon the species and variability of species being treated. Hawaii tests (9, 10) have shown wide differences of susceptibility between species. Therefore, mixtures or sequential applications of different herbicides offer much promise for progress.

For some vegetation mixtures might well yield synergistic effects.

Response to methods of herbicidal treatment varies of course. Generally, individual treatments such as drenching, injection or basal sprays are more effective than blanket treatments such as mist blowing and aerial spraying.

Individual treatments generally are favorable for effective kill in small infestations or in the case of infestations of occasional large shrubs or trees. However, in dense brush stands over large areas or rough terrain, blanket treatment must be employed. Certainly, in many areas of the world with large acreages to be treated, aerial treatment would be the only feasible method of herbicide treatment.

In short the problems with herbicides are: what kind, what rates, what mixtures, and what method of application.

Burning

Under certain conditions, burning offers the most convenient and economical means of weed suppression. For example, Gorse *(Ulex europaeus* L.) (7) and false staghorn fern *(Dicranopteris linearis)* (Burm.) Underw.) burn readily and initial clearing of these by burning should be effective. On Kauai, where there are hundreds of hectares of staghorn fern, burning has been found the most effective means of clearing such land. In fact, if it is to be seeded, removal of the trash is necessary and burning in this instance serves a dual purpose, control and clearing (8).

Mechanical

At this time, stands of large shrubs or small trees would almost certainly require mechanical forms of clearing as they are resistant to herbicides. Herbicides which work best with young growth would then be most effective for maintenance of control.

Using a total program approach, a brush control experiment is being conducted on the Kauai Branch Station (8). This experiment utilizes an integrated program of control, clearing and conversion to pasture. The test area, formerly a pasture but since overgrown with brush, was treated with 2 applications of 4.45 Kg silvex per hectare spaced 8 months apart; burned, and fertilized and seeded by air. Satisfactory forage establishment has been achieved. The remaining objective is to develop this land into a productive pasture using controlled grazing, additional fertilization, spot treatment or whatever else that might promote the conversion.

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6 WEED CONTROL IN HORTICULTURAL CROPS

CHEMICAL WEED CONTROL WITH VEGETABLE CROPS IN HAWAII

R. R. Romanowski, Jr. and Y. Nakagawa[1]

Vegetable crops in Hawaii are grown largely by farmers of Japanese ancestry. There are approximately 720 vegetable farms which comprise a total of 3,200 acres. The many small farms averaging 4½ acres in size are located on the islands of Hawaii, Kauai, Oahu, Maui and Molokai. Many of the cool season vegetables are grown on the island of Hawaii and Maui at elevations of 3,000 to 4,000 feet and the produce is shipped via ocean barges to the population center which is located in Honolulu on the island of Oahu. Essentially all of the remaining vegetables are grown at elevations of 40 to 800 feet. In addition to the variable climates resulting from the differing elevations, several different soil types are used for growing vegetable crops. Silty clay soils are the predominant soil types used in vegetable culture; however, some vegetables are also grown on aa soils, crushed lava rock varying in size from small particles to six inches in diameter and coral sands. Either overhead sprinkler or furrow irrigation is used on most farms. Essentially, all farms have large sized tractors but because of the small limited size of the fields, tractor cultivation is accomplished largely with the use of small gasoline driven hand tractors. Many weeds are still removed by the conventional hand and tractor methods, but chemical weed control is rapidly becoming a necessary tool of culture and approximately 60% of the total vegetable acreage is treated with herbicides, often in combination with tractor and hand methods.

Chemical weed control with vegetable crops first came into use in Hawaii in the mid-1940's. Pentachlorophenol mixed with oil, emulsifiers and water was one of the first chemical mixtures to be used as a directed spray around growing vegetable crops. This mixture was commonly used on sugar cane and pineapple plantations; subsequently the vegetable growers also adopted its use. Baron Goto reported in 1957 at the Fourth Annual Hawaii Weed Conference that only a few herbicides were then used in vegetable crops. He noted that pentachlorophenol activated oil emulsion or DNBP was used for weed control in beans, aromatic solvents for post-emergence weed control in carrots and celery, potassium cyanate for post-emergence weed control in onions and DNBP for pre-emergence control in sweet corn. Vegadex (CDEC) was introduced as a pre-emergence herbicide into the islands in the late 1950's and rapidly developed into one of the most used herbicides in vegetable crops. In the last three years several herbicides have been introduced as evidenced by the information contained in Table 1. At present Vegadex and Dacthal (DCPA) are used to the greatest extent in vegetable culture in Hawaii.

The University of Hawaii, Cooperative Extension Service originally preferred to keep the number of recommended herbicides down to a minimum in order to avoid confusion on the smaller farms, but it was soon found out that the many varying weed species, edaphic and ecological conditions necessitated the use of several herbicides. Tolerant weed species have been one of the most challenging problem areas in the use of chemicals. Results from the vegetable weed research program which was initiated in 1961 immediately predicted that one of the most complex variables in chemical weed control with vegetable crops in Hawaii would be the many differing weed species. Table 2 contains a list of the weed species which are commonly found on vegetable farms. It should be noted that the 41 weed species represent a total of 16 different families. Because of this great diversity in numbers of families under tropical conditions, it can immediately be concluded that a single herbicide often will not control all of the weeds in a given field on a farm. This can be illustrated by the data contained in Table 3.

An experiment was conducted at the Waimanalo Experimental Farm which is located on the island of Oahu to study the weed selectivity of commercially important herbicides. At 50 days after treatment it was evident that some weed species were tolerant to the chemicals under test and equally important the data showed that the above ground populations of tolerant weed species were present in numbers in excess of the check treatment. Similar observations have been made on growers' fields in Hawaii on several occasions namely, that after one or two cropping cycles the repeated use of a given herbicide converted farms over to a monoculture of weeds which were sometimes more troublesome than the original weed population. For example, the data in Table 3 show that the above ground *Cyperus rotundus* population was lower in the check than in the chemically treated plots. This limited stand of nutsedge was attributed to the weed competition from the native weed population. The data from the chemically treated plots also illustrate that the successful removal of undesirable weed species resulted in greater nutsedge populations. The nutsedge population has increased on some vegetable farms in Hawaii since chemical weed control has come into prominence, but continual trials are underway to assist in overcoming this problem with chemicals such as EPTC, PEBC and others. Also, a continual rotation of herbicides on a given field is recommended whenever possible to overcome a build-up of monocultures of tolerant weed species to a specific herbicide.

Soil factors were also found to influence the activity of herbicides in Hawaiian vegetable culture. In general, many of the soil applied pre-emergence herbicides showed similar crop selectivities to those reported in the temperate regions. This was especially true when soil organic matter was taken into consideration. It is common knowledge that soils high in organic matter adsorb certain herbicides making them relatively inactive as regards plant phytotoxicity. Many soils used for vegetable culture in Hawaii contain from 4 to 10% organic matter and often the reduced effectiveness of soil applied herbicides can be attributed to the high soil organic matter. It is also suspected that the inorganic fraction of some fine volcanic ash soils adsorb certain herbicides.

Since vegetable weed control data are somewhat limited under tropical conditions, a series of performance trials were established under varying climatic conditions in Hawaii. As expected the herbicide results

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Weed control in celery: left, dacthal, 9 lb. per acre; right, prometryne, 2 lb. per acre.

Weed control in tomatoes: left, note weeds; right, trifluralin, 4 lb. per acre applied over the plants.

Table 1. Herbicides presently being recommended for use with vegetable crops in Hawaii.[1]

Herbicide	Crops
Alanap-3 (NPA, Sodium salt)	Cucumber, cantaloupe and watermelon.
Aromatic oil	Between row weeding for most widely spaced vegetables.
Atrazine (G-30027)	Sweet corn
Balan (benefin)	Lettuce
Chloro-IPC (C.I.P.C.)	Carrots and onion transplants.
Dacthal (DCPA)	Onions, green beans, daikon, turnip, mustard greens, Chinese cabbage and transplants of onions, broccoli, cauliflower, head cabbage, sweet potatoes, eggplant,peppers and tomatoes. At 4 to 6 weeks after seeding cucumbers, cantaloupes, zucchini squash and watermelons, and at 2 to 3 weeks after seeding lettuce.
Dymid 80W (diphenamid) or Enide 50W	Peanuts and tansplants of peppers, tomatoes and sweet potatoes.
Eptam (EPTC)	Green beans
Lorox (linuron)	Carrots, sweet corn and Irish potatoes.
Methyl bromide	General use in seed beds for most crops except carnations and onions; also used on a field scale by some growers.
Petroleum solvents (Stoddard solvent and others)	Carrots and celery.
Premerge or Sinox PE (DNPB, amine)	Peanuts, green beans, lima beans and Irish potatoes.
Randox (CDAA)	Sweet corn, peas and transplants of onions and sweet potatoes.
Ramrod (CP 31393)	Sweet corn
Tillam (PEBC)	Transplant tomatoes
TOK E-25 (nitrofen)	Carrots, mustard cabbage, Chinese cabbage and transplants of broccoli, cauliflower, head cabbage and celery.
Treflan (trifluralin)	Green beans, lima beans, soybeans and transplants of broccoli, cauliflower, head cabbage, peppers and tomatoes.
Vegadex (CDEC)	Green beans, lima beans, sweet corn, lettuce, soybeans, mustard greens, daikon, turnips, cucumbers, cantaloupes, zucchini squash and transplants of broccoli, cauliflower, head cabbage and celery.

[1]Details on the use of the herbicides listed in Table 1 are contained in University of Hawaii, College of Tropical Agriculture Extension Circular No. 421 "A Guide to Chemical Weed Control in Vegetable Crops in Hawaii."

Table 2. Weed species which are commonly found on Hawaiian vegetable farms.

Scientific Name	Common Name	Family
Amaranthus dubious (A. hybridus)	amaranth, spleen	Amaranthaceae
Amaranthus spinosus	amaranth, spiny	Amaranthaceae
Amaranthus viridus	amaranth, slender	Amaranthaceae
Bidens pilosa var. pilosa	spanish needle	Compositae
Cenchrus echinatus	sand bur	Gramineae
Chenopodium album	lamb's quarters	Chenopodiaceae
Chloris inflata	fingergrass, swollen	Gramineae
Coronopus didymus	swinecress	Cruciferae
Crotalaria mucronata	rattle pod, smooth	Leguminosae
Cuphea carthagenensis	tarweed	Lythraceae
Cynodon dactylon	bermuda grass; manienie	Gramineae
Cyperus brevifolius	kyllinga, green	Cyperaceae
Cyperus kyllingia	kyllinga, white	Cyperaceae
Cyperus rotundus	nut grass	Cyperaceae
Datura stramonium	jimson weed	Solanaceae
Digitaria pruriens	crabgrass, slender	Gramineae
Digitaria pseudo-ischaemum	crabgrass, creeping	Gramineae
Echinocholoa colonum	rice grass, jungle	Gramineae
Eleusine indica	wire grass	Gramineae
Emilia sonchifolia	flora's paint brush; pualele, red	Compositae
Eragrostis pectinacea	love grass, pectinate	Gramineae
Euphorbia hirta	spurge, garden	Euphorbiaceae
Euphorbia thymifolia	spurge, thyme-leafed	Euphorbiaceae
Galinsoga parviflora	galinsoga	Compositae

Table 2 (cont.)

Scientific Name	Common Name	Family
Malva parviflora	cheese weed, pink	Malvaceae
Medicago hispida	clover, bur	Leguminosae
Merremia aegyptia	morning glory, hairy	Convolvulaceae
Nicandra physalodes	apple of peru	Solanaceae
Oxalis corniculata	sorrel, yellow flower	Oxalidaceae
Oxalis martiana	sorrel, pink flower	Oxalidaceae
Phyllanthus niruri	phyllanthus weed	Euphorbiaceae
Portulaca oleracea	pigweed; purslane	Portulacaceae
Richardia brasiliensis (R. scabra)	richardia	Rubiaceae
Setaria lutescens	foxtail, yellow	Gramineae
Setaria verticillata	foxtail, bristly	Gramineae
Solanum nodilflorum or (Solanum nigrum)	popolo	Solanaceae
Sonchus oleraceus	pualele; sow thistle	Compositae
Stachys arvensis	stagger weed	Labiatae
Stachytarpheta cayannensis	vervain, false; joee	Verbenaceae
Tricholaena repens	natal redtop	Gramineae
Xanthium saccharatum	cocklebur; kikania	Compositae

from the high elevation locations, 3,000 to 4,000 feet, correlated well with those obtained in many temperate regions of the world. It is relatively easy to transpose recommendations from temperate regions to those of high elevation locations in Hawaii when soil organic matter and differing weed species are considered. One of the most consistent differences at the low elevation locations, 20 to 800 feet, was the moderate to severe crop phytotoxicity experienced when applying over-the-plant broadcast spray applications. The University of Hawaii, Cooperative Extension Service is conservative when making over-the-plant broadcast spray recommendations in the high temperature low elevation areas. The enhanced crop phytotoxicities can be explained partially by the established principle that herbicide uptake and movement within the plant is more rapid under high temperatures and humidities, but several other factors could be involved in that crops grown at low elevations are very soft and succulent when compared to the same plant species grown at higher elevations.

The above variables were discussed primarily to illustrate some of the observations gained from the Hawaii vegetable herbicide program. It is hopeful that this information can also find application in other Asian-Pacific areas. Hawaii researchers have had to rely heavily on the results obtained in temperate regions of the world in establishing the program because of limited data in the tropics. It was found that many of the same herbicides can be used under tropical conditions when adjustments are made for the differing edaphic and ecological conditions. Also, it was emphasized that weed selectivity performance data are considered as one of the most important variables to be studied under tropical and subtropical conditions.

Hawaii vegetable growers are now enjoying the use of herbicides on 60% of their acreage and it can safely be predicted that this will eventually include most of the acreage even though the complexities are numerous when an agricultural community of 720 farms grow 35 different vegetable crops on a limited acreage of 3,200 acres.

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* Copies of the above are available from the College of Tropical Agriculture, Publications Department, University of Hawaii, Honolulu, Hawaii.

Table 3. Number of weeds per square foot at 50 days after treatment application, Waimanalo Experimental Farm.

TREATMENTS (pounds per acre)	No. of Weeds/sq. ft.						
	Eleusine indica	Setaria verticillata	Phyllanthus niruri	Solanum nodiflorum	Portulaca oleracea	Galinsoga parviflora	Cyperus rotundus
1. Check (no treatment)	0.5	0.6	1.4	6.3	6.5	1.5	1.3
2. Trifluralin 4 lbs. (soil incorp.)	0.0	0.0	0.1	0.0	0.0	0.1	15.5
3. Diphenamid 6 lbs.	0.0	0.0	0.8	16.4	0.0	0.0	4.5
4. Prometryne 4 lbs.	0.0	0.0	0.0	0.0	0.0	0.0	29.5
5. Diuron 4 lbs.	0.0	0.2	0.0	0.0	0.1	0.0	22.2
6. Dacthal 10.5 lbs.	0.0	0.0	0.5	0.0	0.0	4.0	9.0
L.S.D. 5% (1%)	.02 (.03)	0.3(0.4)	n.s.	3.8(5.4)	2.1(3.0)	2.4(3.4)	11.5(16.3)

WEED CONTROL IN TOMATOES

E. E. Chambers[1]

Tomato, *Lycopersicum esculentum,* is native to South America but has now become established around the world. Presently an estimated two million acres are grown. One-fourth of these are in the United States. Although tomatoes are not consumed in large quantities, they are an important food because they are used to enchance or accentuate the flavor of many foods. This use is typical for both fresh and processed fruit.

Because of the nature of use and the subsequent small quantities required, tomatoes command a high price per unit. Their delicate and perishable nature prohibits shipment of fresh tomatoes for long distances. These factors led to concentration of production near large markets and to intensive culture methods. The extreme of this is the greenhouse production of tomatoes in many areas. However, this situation is gradually changing due to greatly improved handling techniques and transportation facilities. There also has been a shift to more processing because of greater convenience.

CULTURAL PRACTICES

The production pattern evolving in tomato culture is directly analogous to many other crops. Production is being concentrated in a few areas most uniquely suited to this crop. Individual grower's acreages are increasing; labor costs are being reduced by mechanization. Other costs including additional inputs of fertilizers and pesticides are increasing. Indications are that this shift will continue. However, in considering tomato weed control today, we must deal with the many varying types of management and the differing intensities of production. This paper discusses production practices in the United States, but the principles are applicable to other areas. The following discussion will point up some of the cultural practices which have an important influence on the weed control program in tomatoes.

Traditionally, tomatoes were established by starting plants in a greenhouse or cold frame and transplanting in the field. Recent developments in planting, harvesting, plant breeding, and weed control have made possible seeding tomatoes directly in the field. Indications are that in the future nearly all tomatoes grown for processing will be established by direct seeding. There will continue to be transplanted tomatoes grown for fresh market as long as early harvest commands a premium price. Of course this situation may change as advances occur in handling and shipping.

In considering tomato weed control in general, an important factor is the method of establishment, direct seeding or transplanting.

All processing tomatoes are grown in the "bush" type culture. That is, the plants are grown without support. Many fresh market tomatoes are trained on trellises.

Mechanized harvest of tomatoes for processing is almost complete. However, the technique is such that heavy weed infestations cannot be tolerated. This indicates a requirement for good, late-season control.

Disease problems affect weed control in two ways. First, since tomatoes are susceptible to a number of diseases including soil-borne pathogens such as *Fusarium* and *Verticillium,* rotation is used to aid in disease control. This can be an advantage if the grower maintains good weed control in the rotational crops. However, too often weed control is neglected and the result is a weed buildup with which one must cope in producing the tomato crop.

The second point concerning disease can be summarized in the statement, "It is easier to prevent or control disease in a weed-free field."

Many tomato fields receive irrigation either as the major source of water or to supplement rainfall. Judicious use of irrigation water can assist weed control whereas failure to consider this factor can aggravate the problem.

Tomato culture stresses good soil preparation. This is true whether establishment is by direct seeding or transplanting. However, the weed control advantage of good seedbed preparation is more than offset by the fact that tomatoes are slow to establish and remain poor competitors throughout the season.

CHEMICAL CONTROL

No attempt will be made to cover exhaustively the work with all tomato herbicides. Rather, those considered most important will be discussed.

Diphenamid

The outstanding herbicide for tomatoes today is diphenamid, N,N-dimethyl-2, 2-diphenylacetamide. Both direct seeded and transplanted tomatoes have shown excellent tolerance to this compound. Limited work on this special problem indicates that tomato plants have a true physiological tolerance to diphenamid. The flexibility of diphenamid has permitted the growers considerable freedom in fitting the chemical into their production program. This herbicide can be applied post-emergence to the tomatoes providing all weeds are destroyed prior to treatment. Layby treatments either directed or topical can be used if the area has not been treated previously or if it is necessary to extend the weed control season.

Perhaps the greatest problem with diphenamid results from the physiological selectivity mentioned previously. The result is lack of adequate control of weeds closely related to tomatoes, especially those in the *Solanaceae* family.

It has also been noted that diphenamid may provide a residual that will injure certain cover crops, especially small grains. In practice, this has not been a serious problem.

Pebulate

Chemically, pebulate is S-propyl butylethylthiocarbamate. It finds wide utility where nutsedge (*Cyperus* spp.) is a problem. As with other thiocarbamates, pebulate requires incorporation immediately after application. This tends to restrict usage to preplant applications. The residual control with pebulate is often not sufficient for the full season. The characteristics of this material have led to a combination treatment with diphenamid in areas where nutsedge is a problem.

Trifluralin

Trifluralin, *a,a,a*-trifluoro-2,6-dinitro -N,N-dipropyl-p-toluidine, has found wide usage in many crops. Two important characteristics which influence use of this chemical are volatility, which necessitates immediate incorporation, and strong adsorption to soil particles. Because it is strongly adsorbed, there is little tendency for this herbicide to leach. This facilitates protection of the crop

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by proper placement of the herbicide and permits use in crops where true physiological tolerance does not exist. Trifluralin is best suited for treating transplants. This herbicide cannot be safely applied on direct-seeded tomatoes at planting; however, it can be used after they are established, but there is the problem of incorporation and of weed control during the critical period of establishment.

Amiben

Amiben is 3-amino-2,5-dichlorobenzoic acid which may be used on tomato transplants if applied in the granular form. However, it has only marginal selectivity, even when used in this manner.

Solan

Solan is 3'-chloro-2-methyl-p-valerotoluidide. It is the only post-emergence compound which has been commercially used in tomato weed control. As can be appreciated from previous comments, a post-emergence material which has little soil residual is of limited utility in tomatoes. The slow growing, poorly competitive crop requires repeat applications to provide a sufficient period of control.

SUMMARY

Efficient, economical production of tomatoes requires a good weed control program. There are several herbicides available but consideration of cultural practices is important in their use. To be most successful, the weed control program should combine chemicals with cultural practices which are aimed at more effective weed control.

WEED CONTROL IN CITRUS

A. H. Lange and B. E. Day[1]

Weed losses and controlling weeds in citrus costs California growers an estimated $23,000,000 per year (16). The control of weeds is essential in the production of citrus. The cost of controlling weeds varies greatly from one citrus growing area to another depending on the soil, the predominant weed species, and the age of the orchard, as well as other cultural practices and environmental factors.

Of the many methods of weed control only tillage, mowing, and chemical treatments are widely used in citrus. Cultivation is always to some extent a cover cropping method since each cultivation is soon followed by a new crop of weeds. Long-term reduction of annual weed populations can be achieved by cultivating frequently enough to destroy weeds before they produce seed. The cultivation schedule should be based on preventing seed-production by the earliest maturing species present and is best determined by inspection rather than by following a fixed schedule.

Cultivation at proper time intervals can ultimately kill deep-rooted perennial weeds by exhaustion of their underground food reserves. Simple perennials are often killed in a season by this process. More complex, deep-rooted weeds with rhizomes, tubers or bulbs with large food reserves are killed only after a rigorously maintained program of cultivation of two or more years duration. Experiments have shown that about sixteen cultivations are required to control bindweed *(Convolvulus arvensis)* (15).

Infrequent cultivations provide temporary relief from weeds but contribute to the build-up of weed populations by increasing the number of buried weed seeds and distributed cuttings, tubers and bulbs. Infrequent cultivation spreads and invigorates perennial weeds by annual weed control and leads to the establishment of solid stands of aggressive resistant species.

Weed control by mowing is effective only against tall-growing species. Where this method is the only means of weed control, low-growing spreading species are given an overwhelming competitive advantage and the orchard goes rapidly to a solid stand of perennial turfgrass.

There has been much progress in the discovery, development, and practical use of herbicides in recent years and these materials have found a place in citrus culture. There are more than 100 commercially available herbicides marketed in some thousands of brands, combinations and formulations. Citrus is relatively tolerant to orchard applications of many herbicides (1,2,3,4,5,6,7).

The trees need not be directly tolerant to foliage applications of contact and foliar systemic herbicides since these chemicals can be selectively applied to weed growth with only minor drift or accidental wetting of the tree foliage. Use of foliar herbicides always results in some degree of soil contamination and it is through this means that tree injury is most likely to occur. For example, when dalapon is applied to the foliage of grasses in orchards it can become leached into the soil reaching a concentration of 1 to 2 ppm in the root zone of the trees causing leaf and fruit drop. With proper application the only hazard in the use of herbicides in orchards is through the soil. For this reason the testing of herbicides for orchard use is a matter of determining the resistance of citrus to soil applications whether or not normal treatments are foliar sprays or direct soil applications.

Contact herbicides were the first to be widely used in citrus orchards. Some California orchards have been maintained weed free with contact herbicides for years with no evident detrimental effects on the trees. Weed oil, fortified weed oil, diquat, paraquat, DMA (disodium methanearsonate), and cacodylic acid are contact sprays that have been used in citrus orchards without showing injury to the trees. Certain petroleum oils, both straight and fortified, are the least selective of all herbicides and are relatively inexpensive in California. For these reasons they are the only general contact herbicides widely employed in citrus orchards. Use of paraquat and cacodylic acid have shown increasing promise for citrus. DMA and other organic arsenicals particularly MSMA (monosodium acid methanearsonate) have controlled certain perennial grasses particularly Johnsongrass *(Sorghum halepense)* and *Paspalum* spp.

Orchard weed control programs may be based entirely on spraying with contact chemicals, although this method is no longer in widespread use. Under this procedure, the orchard soil is laid up in final form and successive crops of weeds are sprayed down soon after emergence and before the earliest maturing species produces seed. The objectives are to prevent seeding of all species, kill perennials through exhaustion of food reserves and ultimately exhaust the seed supply in the soil surface. As spraying continues,

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the population of weed seeds lying close enough to the soil surface to germinate is depleted. Ordinarily by the third year general spraying can be discontinued and the occasional weed that appears can be eliminated by spot spraying, hoeing, or hand pulling. The success of the program is to some extent dependent upon controlling closely adjacent seed sources such as roadsides, fence rows, ditchbanks, and nearby cropland.

Once this spray program is established the grower must entirely abandon cultivation as a soil management procedure. A large population of buried seed remains viable in the soil for many years. Cultivation returns these to the surface and the effects of previous sprayings is largely lost.

Weed control by contact sprays is more expensive initially than maintaining cultivation but results in lower weed control costs over the long term (13).

Weed control programs based on control programs based on contact sprays have the advantage that they are not soil or climate dependent and are applicable to essentially all citrus growing districts throughout the world. In California this procedure, formerly widespread, is now largely limited to the Coachella Valley. This area has exceptionally light soils with low adsorptive capacity for herbicides and frequent flood irrigation which cause soil treatments with residual herbicides to be both hazardous to citrus trees and of only limited effectiveness on weeds.

Soil-residual herbicides are a relatively recent development. Widespread usage began with the employment of monuron in citrus in California in 1955 (6). Herbicides of this type are becoming the most widely used groups in citrus culture.

Citrus is more or less resistant to soil applications of the substituted urea, triazine, and uracil herbicides. Whether or not this resistance is sufficient for selective use of these herbicides in orchards is determined by local soil and climatic conditions and the nature of the weed populations present.

Soil-active herbicides are picked up by roots of plants. Selectivity is based on the amount of chemical absorbed by the roots, plant age, and physiological tolerance. The soil conditions that contribute to selectivity of these herbicides are not clearly understood but appear to be related to the capacity of the soil to absorb a portion of the chemical. Variations in dosage required to control weeds or injure citrus are not fully predictable on the basis of available soil surveys although attempts to make such correlations have been extensive in California. Organic matter, and to a less extent mineral colloids, absorb herbicides (8) maintaining an equilibrium concentration in the soil solution in the upper one to two inches in many soils. Seedling weeds germinate in the zone of greatest concentration of the herbicides and are killed while the deeper-lying roots of the trees receive subtoxic dosages. This, coupled with some degree of natural resistance of citrus, is the basis of the selectivity of monuron, diuron, simazine, bromacil, terbacil and related soil-applied herbicides.

In soils of low adsorptive capacity frequent heavy applications are needed to maintain herbicidal concentrations in the soil surface. More rapid leaching of the compounds under these soil conditions may lead to excessive concentrations in the root zone of the trees. This has been observed in the sandy soils of Florida by Ryan and Dretchman (14) and in California's Coachella Valley. On light-colored, sandy soils rates of substituted urea and triazine herbicides that gave good weed control and injured citrus trees.

The control of weeds in young orchards and in sandy soils is being studied presently in several of the citrus growing areas of California. A number of new herbicides show promise for the selective control of weeds in the propagation of young citrus plantings. One of the herbicides recently registered for use in non-bearing citrus showing promise is trifluralin (Treflan). Incorporated at a depth of two inches, it controls a wide spectrum of weeds with excellent safety to citrus.

In California traizine, substituted urea and uracil herbicides are sprayed on the soil after the orchard is cultivated and ridged to to final form and before weeds emerge. Rainfall or sprinkler irrigation is required to carry the herbicide into the zone where weed seeds germinate. The dosage required to kill weeds is lowest when the weeds are young and increases as plants grow older. Usually 2-4 lb/A of monuron, simazine, diuron, bromacil or terbacil are sufficient to control susceptible weed species in irrigated arid soils. Higher rates may be needed in humid areas with different soil types. Spraying is repeated on an annual or biennial schedule until the weed seeds in the germination zone are depleted. Thereafter, spot spraying, hoeing, or pulling of weeds may suffice for control. Supplemental spraying of contact or translocated herbicides is required for control of resistant weeds.

Translocated systemic herbicides may be used to control annual weeds and spot infestations of perennial weeds. In general, citrus is not sufficiently tolerant to presently available systemic herbicides to permit their orchard-wide use at the rates required to control perennial weeds. 2,4-D is an exception. This herbicide is effective for suppression of field bindweed and other susceptible species at rates up to one pound per acre avoiding direct spraying or excessive drift to the trees. We have seen no injury to mature citrus at rates up to 8 pounds per acre in single or cumulative doses when properly applied. However, severe injury has occurred on young citrus at rates of two or more pounds per acre.

Dalapon has been used for bermudagrass, Johnsongrass, and other perennial grasses when it was sparingly applied to a limited area in the root zone of individual trees and irrigation delayed as long as possible. The rate was kept at the minimum level required to control the perennial weeds. Overdosage, excessive spray run-off to the soil, treatment in sandy soils and immediate heavy irrigation may cause tree injury.

Amino triazole has been used in citrus orchards at rates up to about six pounds per acre without evident injury to orchards. This effective herbicide is extensively used in some citrus production areas of the world, usually in combination with simazine. It is not used in the United States for this purpose because of regulatory sanctions.

Except for weed oils, control based on use of a single herbicide has not been successful. The urea, triazine, and uracil herbicides control a broad spectrum of weed species but resistant species exist. These are often rare and inconspicuous in the orchard flora when treatment is initiated and weed control is judged to be complete. However, if not initially present, certain euphorbias, composites and a variety of perennials, once introduced, thrive free of competition and ultimately take over the orchard.

Species build up can be prevented by alternating herbicides. Spotted spurge *(Euphorbia supina)* in California is resistant to all three classes of soil residual herbicides and is normally controlled by occasional spot teratment with petroleum oil. With normal vigilance reinvasion by resistant species is usually not serious.

Non-cultivation based on contact sprays has been practiced to some extent in citrus orchards in California for about 40 years. Since the development of soil-acting herbicides more than a decade ago this management procedure has extended to about three-fourths of the 250,000 acres of citrus in California, including nearly all of the orchards in which soil treatments can be safely and effectively applied. The practice has successfully extended to some degree into other arid-land citrus production districts of the world. It has not been gererally successful in humid regions for reasons that are only partially understood. Much higher rates of simazine and diuron are necessary for annual weed control in soils similar to those found here in Hawaii and under more tropical conditions.

The general value of non-cultivation as a horticultural practice in citrus has not been widely studied. Jones et al. (10) have shown that it can lead to striking increases in yield. Net soil water intake increased after conversion from tillage to nontillage. Fruit from nontilled plots compared with cover-cropped plots was larger with lower Brix, lower in percentage of juice, a higher Brix/acid ratio and a thinner peel. How generally we can apply their study is not known. Based on observation, it is widely believed that non-cultivation is beneficial because of increased yield, improved quality earlier maturity, improved water penetration, less soil erosion, reduced fertilizer use, reduced rodent damage to trees, reduced root injury from tillage equipment, and reduced frost hazard (9,10,13). Leyden (11, 12) reported reduced frost hazard with temperatures 2-3^{o} C warmer in non-cultivated orchards on cold winter nights. Non tillage is widely employed for these and other reasons, but largely because of greater convenience and economy of orchard management.

Effective weed control programs utilize all applicable methods. The best combination varies from orchard to orchard depending upon weed flora, soil and climatic conditions and the degree of weed control needed. Where suitable, soil-active herbicides are used to control weeds originating from seed and as such are the basic treatment in the program. Contact or translocated herbicides are always necessary as supplemental treatments to control resistant annuals and established perennials. Cultivation and mowing are used where herbicides cannot be used. Weed should be controlled in adjacent land areas and around structures and ditches in the orchard to reduce sources of reinfestation. Such programs will reduce the expense of orchard maintenance, increase efficiency of operations, and appear to generally benefit the trees.

Weed control is a community venture and should extend across property lines and include adjacent and intervening noncrop areas. Weed control measures are most effective when applied throughout an entire agricultural district.

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SELECTIVE CONTACT HERBICIDE FOR CITRUS ORCHARDS

Tadashi Hisada[1]

Recently herbicides have been used in citrus orchards to save labour, but an effective selective herbicide has not been discovered. The new herbicide developed by our laboratory has many characteristics for citrus orchards. I would like to report why we have come to develop this specific herbicide.

In Japan at present the following citrus is grown: Satsuma orange, Satsuma mandarine, Japanese summer orange, and other citrus fruits. The acreage of citrus orchards in 1965 was approximately 150,000 hectares. Generally, citrus orchards are distributed on sloping ground along the coast of Southwest Japan.

Recently there is a trend toward "sod culture" rather than "clean culture" in view of climatic conditions and methods of culture. That is, "sod culture" is able to supply the organic matter to prevent soil erosion during rainy seasons. In "sod culture", 3 or 4 mowings are required during the summer season, and there are problems in controlling weeds.

The following are some principles which must be considered when using herbicides in citrus orchards:

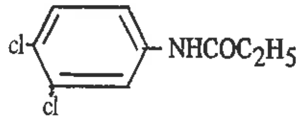
1. Instead of mowing, we use a herbicide in the expectation that weeds may not be eradicated completely; the grass should be regenerated after treatment for weed control, and the duration of effect is expected for 40 to 60 days.

2. The herbicide itself must be very effective. In order to prevent soil erosion, the treatment for weed control should be made after the rainy season. This means that the herbicide would be used against fully-grown weeds. The vicissitude of weeds in the orchard and height of summer weeds is given in Fig. 1, and Fig. 2, using crabgrass *(Digitaria adscendens* Henr.*)* as the typical weeds.

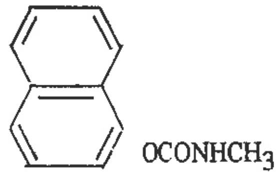
In Figure 1, the vertical axis shows height of grass, and the horizontal axis date, and a dotted line depicts spring weeds while a solid line depicts summer weeds. The control of summer weeds is more important than that of spring weeds, because summer weeds attain the highest growth under high temperature condition. As shown in Fig. 2, these weeds germinate in late spring, grow during June, reach the maximum height in July and begin to wilt in September. In this case, grass heights are about 60 to 80 cm. and occasionally may reach one meter early in July when the rainy season has finished.

3. Herbicide itself must be selective. Even if the herbicide is sprayed on the citrus trees directly, it should be non-toxic because citrus trees usually are planted on sloping ground, and it is impossible to avoid the citrus trees under windy conditions. Moreover, the height of the young citrus trees and the height of the weeds to be controlled in the nursery garden are very close; therefore, good selectivity is required in this case.

The new herbicide WYDAC contains two components as active ingredients. One is 3,4-dichlorophenyl propionanilide (DCPA), which is used in rice culture. This compound



is generally known as propanil and sold under trade names of Stam, Rogue, Sulcopul, and DCPA. The other component is 1-Naphthyl N-methyl carbamate, which is an insecticide known as Carbaryl, Sevin, or Denapon.



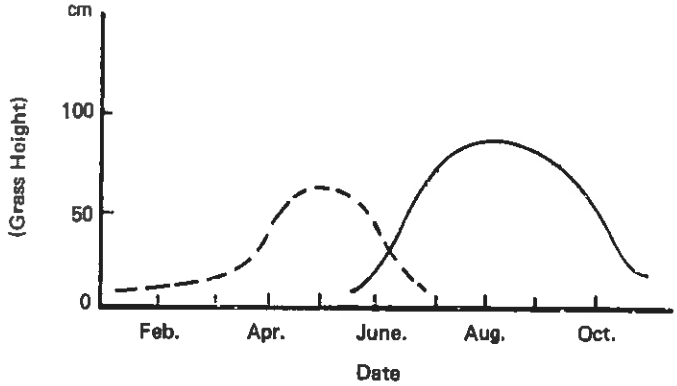


Figure 1. Vicissitude of weeds in citrus orchard.

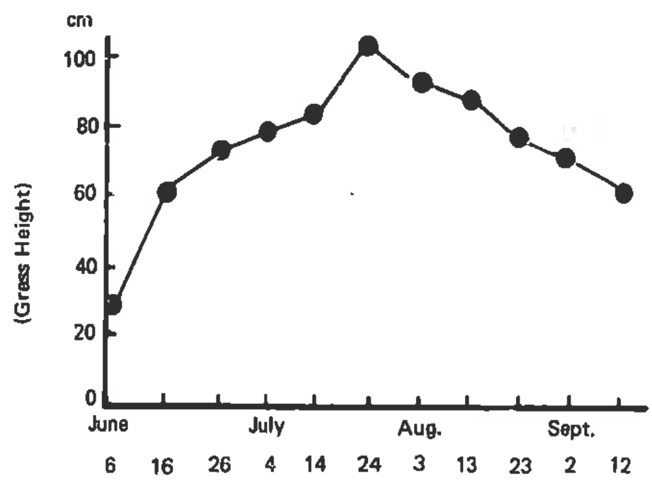


Figure 2. Height of crabgrass *(Digitaria adscendens Henr.)*

[1]Chief Research Chemist, Hodogaya Chemical Company, Tokyo, Japan.

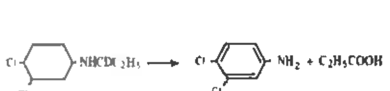
In Japan this insecticide is used generally for control of greenrice leafhopper *(Nephotettix cincticeps* Uhler) and brown planthopper *(Nilaparvata lugens* Stal) in rice fields from May to August. The most interesting thing here is that the combination of the herbicide with an insecticide was found more effective than just the weed killer.

When propanil and Carbaryl were applied in rice fields, the phytotoxicity was accelerated all the more; however, single application of propanil did not show phytotoxicity under normal conditions. Since we have recognized this unique severe phytotoxicity through the use of propanil and Carbaryl at the same time, we tested many pesticides with propanil to find the synergistic action of phytotoxicity. As a result, we found that the following chemicals had synergistic phytotoxicity:

a) Carbamate compound:
   1-Naphthyl N-methyl carbamate
   2-Naphthyl N-methyl carbamate
b) Organo phosphorous compound:
   0,0-diethyl 0-4nitrophenyl phosphorothioate
   0,0-dimethyl 0-3-methyl 4-nitrophenyl phosphorothioate

For example, synergistic action of 1-Naphthyl N-methyl carbamate is shown in Fig. 3. The vertical axis shows ED value, that is 100% means complete control, and 0% means no effect. The horizontal axis shows the concentration of active ingredient, the sigmoid curved solid line shows propanil only, whereas the dotted line curve shows a mixture of 5 to 1 ratio of propanil and Carbaryl. There is a striking difference between propanil only and propanil plus Carbaryl. That is, propanil shows complete control at 6%, on the other hand propanil plus Carbaryl shows complete control at around 1%.

Formerly, the selective action of propanil for rice plants was studied by many workers. According to the latest report (Adachi, 1965), the selective action of propanil for weed control in rice fields is caused by the enzyme concerning hydrolysis of propanil in rice plant tissues. They concluded by use of tissue homogenates of rice plants, that DCPA (3,4-dichlorophenyl propionanilide) is hydrolyzed to 3,4-dichloroanilin and propionic acid distinctly, but the homogenates of barnyardgrass and other weeds which are controlled by propanil have low DCPA decomposing activity.



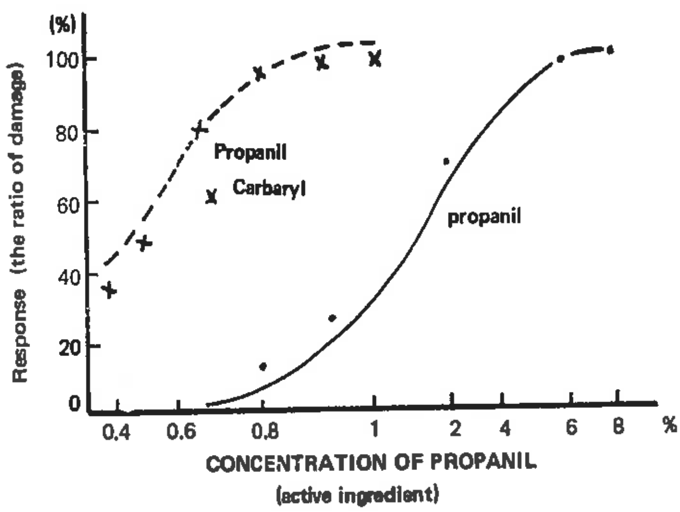


Figure 3. Synergistic action of Carbaryl for rice plant. (3 to 4 leaf stage).

TABLE 1. Decomposing activity of homogenate.

Plant Species	DCPA 24 hr.	DCPA 48 hr.
Barnyard grass *(Echinochloa crusgalli)*	58 µg	56 µg
Asiatic dayflower *(Commelia communis)*	44	34
Pinkweed *(Polygonum longisetum)*	59	57
Rice	19	10

(by Adachi, 1965)

TABLE 2. Influence of pesticide for DCPA decomposition activity.

Pesticide	Added Pesticide	Added Propanil	DCA
no added	– µg	125 µg	103 µg
PMA	200	125	88
BHC	200	125	82
Carbaryl	200	125	5

(by Adachi, 1966)

TABLE 3. Herbicidal effect for crabgrass (grass height 50-60 cm.).

Name	Dosage active ingredient per 10 acre	Degree of Effectiveness	Response
Propanil	500 g	3	survival of weeds which grew vigorously
Propanil + Carbaryl	500 g + 100 g	10	completely killed
Sodium cyanate	3000 g	4	

The effect of weed control rated from 0 to 10 scale, 0 is no effect and 10 is complete kill.

Table 1 shows the inactivation of propanil by the tissue homogenates of different plants. 62.5 µg of propanil was mixed with tissue homogenate and the amount of propanil undecomposed was analyzed after 24 hours and 48 hours. Adachi assumed that the selectivity of propanil is due to the enzyme to hydrolyze propanil. Table 2 shows the influence of pesticides on the activity of the enzyme to hydrolyze propanil. 125 µg of propanil was mixed with tissue homogenate of rice plant and the decomposed product (3,4-dichloroaniline) DCA was analyzed after 24 hours.

Adachi assumed that Carbaryl is probably acting as an inhibitor of this hydrolyzing enzyme. As shown in the results, there is a significant relationship between the enzymatical studies and the practical spray test. We studied the activity of the new herbicide. Generally 3,4-dichlorophenyl propionanilide shows high effect against the young stage of weeds, and the highest effect is expected by spraying at the 2-4 leaf stage, but it does not show any effect against old weeds. On the contrary, the new herbicide shows high activity against many species of weeds, even if the grass height is above 60 cm. and fresh grass weight is over 3 kg/m. As shown in Table 3, crabgrass which is very difficult to control by propanil in this case was completely controlled by adding Carbaryl to propanil. Furthermore, we have found that the new herbicide has interesting selective action for some woody species. Generally this herbicide does not harm certain plants which contain waxy substance in the epidermis of the leaves; citrus is very tolerant of this herbicide. The results for selective action of this herbicide are given in Table 4 and 5.

Moreover we are studying mechanism but at present it is not clear. We infer as follows: Firstly, the selective action of this herbicide will depend on the difference in its penetration between cirtus trees and weeds. Secondly, it will depend on the difference in its detoxication activity between citrus trees and weeds.

Table 4. Influence of herbicide on citrus tree.

Herbicide Name	Dosage a. i. g. /10 a.	Observation
DCPA + Carbaryl	250 + 50 500 + 100	Defoliation and chlorosis were not observed.
Sodium cyanate	4,000	5 days after treatment, 95% of total leaves were defoliated.
Diquat	150	3-4 days after treatment, all leaves were defoliated.
ATA	450	10 days after treatment, chlorosis was observed.

Each herbicide was diluted to 150 liter/10a. and sprayed.

Table 5. Damage to woody plants.

Common Name	Scientific Name	Degree of Damage [1]	Observation
Pine	*Pinus densiflora* Seib. et Zucc.	–[2]	Normal
Larch	*Larix leptolepsis* Gold.	X to + + + + + + +	Colored dark gray, defoliated, killed
Himalayan ceder	*Cedrus deodara* Loud.	– –	Normal
Cryptomeria	*Cryptomeria japonica* D. Don.	– –	Normal
White ceder	*Chamaecyparis obtusa* Endl.	-- –	Normal
Juniper	*Juniperus chinensis* var, *Saragenti.*	– –	Normal
Oak	*Quercus myrsimaefolia* Blume.	+ + +	Colored dark-green, defoliated at a touch.
Pasania oak	*Castanopsis cuspidata* Schottky.	+ + + + to + + + + + to +	Colored dark-green, defoliated, killed.
Camellia	*Camellia japonica* L.	– –	Normal
Plane-tree	*Platanus acerifolia* Willd.	+ + + to + + + +	New leavee killed, old leaves partially killed
Cherry	*Prunus yedoensis* Matsum.	+ + +	
Rose Bay	*Rhododenddron indicum* Sweet.	+ + + + +	Colored dark-green, partially killed.
Japanese Aucuba	*Aucuba japonica* Thunb.	– –	Normal
Spindle tree	*Eunymus japonicas* Thunb.	+ +	Defoliated at a touch, partially killed.
Holley	*Ilex crenata* Thunb.	– –	Normal
Torreya	*Torreya nucifera* Sieb. et Zucc.	– –	Normal
Mandarine	*Citrus Unshiu* MANC.	– –	Normal
Japanese summer orange	*Citrus Natsudaidai* HAYATA.	± –	Normal

[1]X . . . . killed
+ + + + ... severe damage
+ + + ... moderately
+ + ... slightly

[2]upper . . . . 1.0% solution;
lower . . . . 0.5% solution (as active ingredient)

WEED CONTROL IN COFFEE AND MACADAMIA ORCHARDS IN HAWAII

Edward T. Fukunaga[1]

Although chemicals to control weeds have been used for special purposes in Hawaii since the early 1900's, weed control in coffee and macadamia orchards was done entirely by mechanical methods until the early 1930's. The change-over from mechanical to chemical weed control was slow, however, in spite of the fact that sugar plantations in Hawaii began using chemicals to control weeds quite extensively by the mid-1930's. Not until the U.S. entry into World War II, when labor became scarce and high priced did chemical weed control become well established in coffee and macadamia orchards. By the end of the war, all coffee and macadamia growers were using herbicides exclusively or partially to control weeds.

Chemical weed control not only reduced weeding costs, but also made it possible to grow coffee and macadamia nuts on slightly weathered lava lands or lands which are extremely stony. The advent of the bulldozer greatly facilitated clearing heavily forested lava lands which are extremely rough. Adequate weed control is impossible by mechanical methods on such lands and the use of herbicides is the only economical method of weed control. Coffee and macadamia plantings made after World War II in Hawaii are almost entirely on lava lands. Since chemical weed control is necessary on such lands, a great effort was made to develop suitable herbicides. At present, weed control in coffee and macadamia orchards of Hawaii is done entirely by chemical means.

During the early stages of chemical weed control, coffee and macadamia growers relied entirely on chemicals developed by the sugar and pineapple industries. The earliest herbicide used in quantity was the so-called "self boiling" concentrate. This concentrate was prepared on each farm by placing measured amounts of caustic soda and white arsenic (arsenic trioxide) in the bottom of a suitable container and adding a measured amount of water to the two ingredients. The reaction of white arsenic with caustic soda liberated sufficient heat to cause the solution to boil, hence the name. This concentrate was diluted with water before using.

The preparation of self boiling concentrates on the farm entailed considerable danger and difficulty. The concentrate often splattered during preparation and caustic soda caked during storage. Because of this, the preparation of self boiling concentrates on the farm ceased as soon as factory prepared liquid concentrates became available.

The active ingredient in these early herbicides was sodium arsenite. The undesirability of using arsenicals continuously in large quantities on the same land is well known and sugar plantations, which were using arsenical herbicides during the 1930's and early 1940's began, to look for other herbicides or means to permit the use of less arsenic without reducing the efficacy of the herbicide.

Some plantations began adding sodium chlorate to the arsenic herbicide to cut down on the amount of arsenic necessary. During the late 1930's sodium pentachlorophenate (NaPCP) began to replace sodium chlorate as an additive to the sodium arsenite. NaPCP was then called "activator" since it was thought that it made the herbicide more active.

Petroleum oils were known to be good herbicides, but were not acceptable because of their high cost. It was then found that an economical herbicide could be prepared by adding NaPCP to an emulsion of diesel oil. This was the most important herbicide in the sugar and pineapple plantations during the mid 1940's. The sugar plantations prepared an emulsion concentrate called "CADE" which was an abreviation of "concentrated, activated, diesel-oil emulsion". CADE was diluted in water before using.

Various types of petroleum products were tested during the mid 1940's, and it was found that aromatic oils were more active as herbicides than aliphatic oils. Diesel oil consists mainly of aliphatic oils. It was also found that oils with a high proportion of aromatic compounds would dissolve pentachlorophenol (PCP).

PCP has several notable advantages over NaPCP. PCP is cheaper with longer residual action, and is less irritating than NaPCP. There have been many instances where persons allergic to NaPCP could handle PCP without adverse effects.

The only disadvantage of PCP is its insolubility in water. It must therefore, be dissolved in aromatic oil first before the oil is emulsified. PCP does not dissolve readily in cold aromatic oil, but it dissolves readily when the oil is heated to about 60°C. At first, coffee and macadamia growers made their own PCP in aromatic oil solutions on the farm using makeshift heating devices–usually a 55-gallon drum placed over a crude wood burning stove. However as factory-prepared PCP-aromatic oil concentrates became generally available, farmers gradually stopped preparing their own solutions. The factory prepared PCP solutions also contained a "built-in" emulsifier. This increased the cost, but the convenience of using these prepared solutions outweighted the economy of home-made products so that farmers soon turned to the prepared product.

Emulsifiers for emulsifying diesel oil and later the home-made PCP-aromatic oil solutions presented problems during the years immediately following World War II. Suitable emulsifying agents were not readily obtainable. Soaps were used at one time and a soap making factory was established in Hilo to supply this need. Soaps do not dissolve readily in cold water, however, and had to be dissolved either a day or two before using or dissolved in hot water. This was a cumbersome process and its use soon became a thing of the past as other more readily soluble emulsifying agents became available. War surplus salt water soaps became available for a fraction of their actual cost for a time and were used while the supply lasted. The sap of the amau fern *(Sadleria cyatheoides)* was also used at one time. A factory to extract the sap from this fern was established in Hilo and supplied emulsifiers to farmers and plantations for a few years.

PCP-aromatic oil emulsions continued to be used in coffee orchards, but tests proved that oils sprayed on macadamia nuts penetrated the shell and were absorbed by the kernel imparting a bitter taste to the kernel even when the outer husk was intact. Its use was therefore restricted to young, non-bearing orchards. At present PCP is prohibited in macadamia orchards.

The changeover from arsenicals to "activated" oil emulsions was difficult. Ar-

[1]Horticulturist, Kona Branch Station, University of Hawaii.

senicals, especially when factory prepared concentrates were used, were easier to prepare and considerably cheaper. Farmers were therefore quite reluctant to change herbicides in spite of the efforts of the Extension Service and Experiment Station. However, the passage of the Pesticide Chemicals Amendment to the Federal Food, Drug and Cosmetic Act, commonly known as the Miller Law, which became effective in 1956, forced farmers to abandon the use of arsenical herbicides in food crops. Pesticide dealers of Hawaii cooperated by refusing to sell arsenicals to farmers. Farmers were, thus, forced to change to petroleum oils which could be used under a grandfather clause in the pesticide regulation drawn up under the Miller Law.

Under the provisions of the Miller Law, each pesticide must be cleared before use on any crop. Obtaining clearance was a problem since no laboratory facilities existed in Hawaii to do the necessary chemical analyses for general agricultural crops other than sugar and pineapple. The cooperation of the manufacturer of the herbicide was necessary. This was easy to obtain for crops like coffee, where although the acreage in Hawaii was limited, the world coffee acreage was considerable. There were only a few thousand acres of macadamia nuts, hence pesticide manufacturers were reluctant to speed thousands of dollars to clear a pesticide when the potential use of the material was limited to macadamia orchards. In the case of the PCP manufactured by several different manufacturers, no single manufacturer was willing to expend the necessary money to do the required analyses and legal work.

Dalapon was the first herbicide cleared for coffee and macadamia orchards. The manufacturer of the herbicide agreed to do the laboratory and legal work necessary for clearance of this herbicide on coffee but declined to do this for macadamia. Consequently, the largest macadamia nut grower at the time hired a mainland laboratory to do the analyses. The manufacturer of the herbicide, however, did the legal work. Dalapon was cleared for use in both coffee and macadamia orchards in 1961.

Similar work was carried out to clear atrazine, simazine, diuron, and paraquat for coffee and macadamia nut orchards. All field work on coffee was done by Experiment Station personnel, while the field work on macadamia nut was done by both Experiment Station and private industry personnel. At present, atrazine, simazine, diuron and dalapon are cleared for use in macadamia orchards while dalapon and PCP (in aromatic oil) are cleared for coffee orchards. Paraquat is now cleared for non-bearing orchards and it is hoped that in the near future it will be cleared for bearing orchards as well.

Several other herbicides have proven effective in coffee and macadamia orchards, but clearances have not been attempted because of questionable economic factors and the lack of any real need. Any new herbicide to be cleared must be more economical than material already in use, in addition to being effective.

Many problems and difficulties have been encountered in herbicide clearance work. One is the small acreage of crops like macadamia nut. The potential use of the material on these crops is limited and manufacturers are reluctant to spend large sums of money to obtain clearance. The recently established analytical laboratory for pesticide residue analyses in Hawaii should remove this difficulty.

Although PCP-aromatic oil emulsion was developed for weed control in Hawaii, it could not be cleared because none of the several manufacturers was willing to undertake the necessary clearance work. It was, however, cleared for coffee orchards elsewhere.

Many of the chemicals used were new and suitable analytical methods had not been established for all crops. Methods for isolating the chemical ingredient from the product for analysis sometimes differ from crop to crop. For example, amitrole was found to be an excellent herbicide to control certain weeds which resist herbicides cleared for use in coffee orchards. Coffee trees proved much more tolerant to amitrole than macadamia trees and many other crops on which it was tested. Since no analytical method had been developed for determining amitrole content in coffee beans, the manufacturer awarded a grant to the Hawaii Agricultural Experiment Station to develop a method and do the analyses. A completely satisfactory method could not be developed within the limited grant because of an interfering substance in the coffee bean. The widely publicized "cranberry scare" occurred while the work was still in progress and all work with amitrole on coffee was dropped.

Herbicides have become more specific, not only as to the type of weeds controlled as well as tolerance of the various crops to each specific chemical. Diuron, for example, is relatively safe to use in macadamia orchards, but coffee trees are somewhat more sensitive to this herbicide. Because of this, no attempt has been made to clear this herbicide for coffee.

Weather conditions also affect the efficacy of the herbicide. Too much rain reduces the effectiveness of certain herbicides while others are not effective unless the soil surface is moist. Hence the effectiveness of certain types of herbicides varies according to the season. One herbicide may often be reported very effective in one area while this same herbicide on the same crop in another area may be appreciably less effective.

Chemical weed control has become very efficient in recent years. Not only the actual herbicide but also the surfactants have greatly improved so that material previously considered strictly a pre-emergence herbicide will kill existing weeds when properly combined with suitable surfactants. Before pre-emergence herbicides became available, coffee and macadamia orchards had to be sprayed 4 to 6 times during the year to keep the weeds under reasonable control. Macadamia orchards can now be kept completely weed-free for all practical considerations with only two blanket spraying of herbicide combinations per year.

The term "weed control" in such cases seems to be obsolete. The area of complete weed eradication or completely clean culture may soon be in the offing.

WEED CONTROL IN BANANAS AND PAPAYAS IN HAWAII

Joseph A. Crozier, Jr. and R. R. Romanowski, Jr.[1]

Banana *(Musa sp.)* and papaya *(Carica papaya)* are important crops in Hawaii. In 1965, together, they comprised almost 80 percent of the acreage of fresh fruit grown in Hawaii, which represented 15 percent of the acreage devoted to diversified crops excluding the two major crops, sugar cane and pineapple. The total acreage of banana and papaya reported that year was approximately 931 hectares, divided almost equally between the two crops. From this acreage, however, $1,833,000 was produced for the farmers of Hawaii, representing about 15 percent of the total value of diversified crop production in Hawaii (1). Diversified crops include vegetables, melons, fruits, coffee, macadamia nuts, and taro.

Research in chemical weed control on these crops was initiated by the College of Tropical Agriculture of the University of Hawaii in 1962 (3). At that time very few herbicides were registered for use with the FDA (Federal Food and Drug Administration) with either of these crops. Dalapon was registered for grass control in bananas. Aromatic oil was the only herbicide registered for use with papayas. Both herbicides however, left large gaps in the weed control picture in Hawaii.

Among those herbicides included in the initial screening trials in Hawaii were ametryne, atrazine, amitrole, 55 AR oil, bromacil, dalapon, diquat, diuron, EPTC, linuron, MSMA, norea, paraquat, prometryne, PCP (Na), pyriclor, PEBC, picloram, trifluralin, and various combinations of several of these (2). Not all were tried on both crops but the early trials led to subsequent tests of the more promising herbicides. From the outset, it was found that certain of the above herbicides were extremely toxic to the crops under consideration. For example, bromacil and picloram caused severe injury to bananas even at low dosages and can now be considered for use as eradicants where diseases have become a problem or for situations where bananas are no longer desired (2). Even with other herbicides such as atrazine, widely used on many crops in Hawaii, severe marginal burning occurred with bananas at rates of 3.3 to 8.3 kg/ha. This led to a several months delay in harvesting and seriously reduced yields. Paraquat at rates of 1.1 to 2.2kg/ha. as well as other contact herbicides caused injury on young banana plants when spray drifted on the leaves. This injury caused stunting but the plants recovered as the new leaves developed. Older banana plants were not affected as the sloughted leaves protected the base of the plants. A more severe reaction occurred when paraquat was applied to young papaya trees with green bark on the trunks. The trunks were severely injured by the spray drift and the damaged tissue permitted fungi, bacteria and insects to enter and soon the young trees collapsed. With the older trees in which bark had toughened this problem was negligible.

Even with diuron, a herbicide which gave very good performance in both crops, some problems were encountered on subsoils which had just been freshly excavated (2). With bananas a definite chlorosis and stunting of the plant occurred. In papaya, a veinal chlorosis occurred within several days after treatment on all the leaves present at the time of application. The new leaves failed to exhibit this striking pattern. Again the soil pattern was similar to the situation which occurred with the banana.

Some of the above problems have been overcome by different methods such as wrapping the trunks of the young papaya plants to protect them from drift of the contact herbicides, and avoiding shallow, freshly excavated sub-soil for both crops. Nevertheless, certain problems continue to confront the researcher in Hawaii. Approximately 80 percent of the papaya acreage in Hawaii is grown on lava rock-soil complexes with the remainder being grown on mineral soils of volcanic origin which are greatly weathered and leached by frequent rains. These factors have necessitated the search for herbicides with post-emergence activity.

The decision was made to develop at least one or two chemicals if possible which would do the best job for the longest period of time with both crops. After the first series of screening trials, the decision was made to continue to work with paraquat, diuron on both crops and ametryne on banana only.

It must be pointed out that several other herbicides were satisfactory in both weed control and safety on the crops but due to the concern for clearance of one of the most promising herbicides, the decision was made to concentrate on the above mentioned chemicals.

All of the herbicides were applied as spray mixes with water as the diluent in back-mounted fiberglass tanks pressured with nitrogen gas. The spray was directed to the base of the plants at 90 liters of spray mix per hectare.

The herbicides tested (particularly diuron) were often applied more frequently than necessary for adequate weed control to facilitate FDA registration requirements.

The weed data were recorded using a subjective rating scale based on the tolerance to the herbicides for each weed species found uniformly in the plots (See Table 1.)

Complete data for all the banana trials are found in the appendix of reference (3).

A general summary of the relative tolerance of the weeds to post emergence applications of the above mentioned herbicides is found in Table 1. The results from three screening trials on both banana and papaya for the past five years showed that diuron at 2.2 to 4.5 kg/ha. plus surfactant gave excellent results both pre- and post-emergance for periods from three to six months follow-application with most weeds listed in Table 1. Occassionally, a veinal chlorosis was observed in both crops, but particularly in papaya, and seemed to be related to the organic matter in the soil and still needs to be further investigated. This effect was observed when sub-soil areas were sprayed as compared to lack of symptoms when adequate top-soil was present.

Paraquat at rate of 1.1 kg/ha. plus surfactant gave very good control of these weeds, in both crops for periods from one to three months, Table 1. Young papaya plants should be protected to prevent contact injury to tender stems and foliage.

Ametryne at rates of 4.5 to 9.0 kg/ha. showed considerable promise in bananas for periods up to four months and appears to be safe on young plants in mineral soils. It was noted that one troublesome weed species, button-weed, was resistant to ametryne and the plots soon became a monoculture of this weed, Table 1. However, good control was obtained with other weed species which were not easily controlled by diuron.

Studies are currently in progress so that ametryne and paraquat can be registered at the earliest possible date with bearing

[1]Assistant and Associate Horticulturists, respectively, Hawaii Agricultural Experiment Station.

Table 1. General summary of the relative tolerance[1] of the weeds[2] to postemergence applications of the herbicides.

Chemical	Grasses and Sedges						
	crabgrass	foxtail	jungle ricegrass	lovegrass	nutsedge	sandbur	wiregrass
Ametryne	S	I-S	I-S	I-S	T	S	S
Diuron + X-77[3]	I-S	S	I-S	S	T	S	S
Paraquat + X-77	S	S	T-I	I-S	I	S	S

Chemical	Broadleaves						
	Flora's paint brush	button-weed	fine leaved celery	purslane	smooth amaranth	Spanish needle	swine-cress
Ametryne	I-S	T	T-I	S	S	S	S
Diuron + X-77	T-I	S	S	S	S	S	S
Paraquat + X-77	S	I-S	S	S	S	I-S	I

[1]Weed tolerance: T - Tolerant to herbicide
I - Intermediate (often influenced by soil type)
S - Susceptible

[2]Scientific names of weeds encountered in the screening trials.

Grasses
- crabgrass *(Digitaria sanguinalis)*
- foxtail, bristly *(Setaria verticillata)*
- jungle ricegrass *(Echinocholoa colonum)*
- lovegrass *(Eragrostis pectinaceae)*
- nutsedge *(Cyperus rotundus)*
- sandbur *(Cenchrus echinatus)*
- wiregrass *(Eleusine indica)*

Broadleaves
- Flora's paint brush *(Emilia sonchifolia)*
- buttonweed *(Borreria laevis)*
- fine leaved celery *(Apium tenuifolium)*
- purslane *(Portulaca oleracea)*
- smooth amaranth *(Amaranthus hybridis)*
- Spanish needle *(Bidens pilosa)*
- swinecress *(Coronopus didymus)*

[3]The non-ionic surfactant Multifilm X-77 from Colloidal Products was used at the rate of 0.2% V/V.

Table 2. Suggested guide for chemical weed control with bananas in Hawaii.

Herbicide	Rate (Commercial product)	Remarks
Aromatic oil	375 to 935 1/ha.	Use lower rate on small weeds. Be careful of bleaching fruits from vapors.
Dalapon	8.9 to 14.5 kg/ha.	Apply before grass heading stage in 750 to 935 1/ha. of spray mix. Do not apply more than 29 kg/ha. per year.
Diuron plus surfactant	4.5 to 5.6 kg/ha.	Apply only after the plants are established and keep away from the base of newly set plants. Treat cautiously on lighter soils. Apply as a basal spray either as a pre-emergence treatment (no surfactant) in 375 1/ha. of spray mix, or as a post-emergence treatment on emerged weeds (with surfactant) in 750 to 935 1/ha. of spray mix. Use 0;5 to 1 liter of X-77 surfactant per 375 liters of spray mix or equivalent. Do not apply more than 13 kg/ha. of diuron per year. Do not plant other crops in the area for two years after last treatment.
Trial Use[1]		
Ametryne	5.6 to 11.2 kg/ha.	Apply immediately after setting plants or any time thereafter. Apply as a basal spray either as a pre-emergence treatment in 375 1/ha. of spray mix or as a post-emergence treatment on emerged weeds in 750 to 935 1/ha. of spray mix. Apply ametryne at 3 to 4 month intervals as necessary.
Paraquat plus surfactant	2.3 to 4.6 1/ha.	Apply as a basal spray to emerged weeds in 750 to 935 1/ha. of spray mix. Use 0.5 to 1.0 liter of X-77 surfactant per 375 liters of spray mix or the equivalent of non-ionic spreader-sticker. Registered for use only in non-bearing plantations.

[1]Trial Use: Ametryne and Paraquat should be used only on an experimental basis until Federal registration is obtained (discard treated fruit).

Table 3. Suggested guide for chemical weed control with papaya in Hawaii.

Herbicide	Rate (Commercial Product)	Remarks
Paraquat plus surfactant	2.3 to 4.6 l/ha.	Apply as a directed spray to emerged weeds in 750 to 935 l/ha. of spray mix. Use 0.5 to 1.0 liter of X-77 surfactant per 375 liters spray mix or equivalent of a non-ionic spreader-sticker. Spray contact on green succulent trunk may cause injury. Use on non bearing trees only.
Pentachlorophenol (PCP)	4.5 to 11.2 kg/ha.	Dissolve PCP in aromatic oil and add water to which an emulsifier has been added. Generally, 450 grams of PCP is mixed with 16 liters of petroleum solvent. Do not apply after fruits start to form.
Petroleum solvents	375 to 935 l/ha.	Apply as directed spray to small weeds on an as needed basis.

bananas. Paraquat is now registered for use in non-bearing banana and papaya plantations.

Dalapon which was one of the few herbicides registered for use with bananas gave adequate control of grasses but did not control broadleaf weeds. Aromatic oil is still being used by the small growers as a cleanup contact spray but may bleach fruits from the vapors and should be used with care.

Suggested guides for chemical weed control in Hawaii, based on the current investigations, are presented for bananas in Table 2, and for papayas in Table 3.

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Top: Banana, young plantation. Shows importance of weed control early in life of crop. Note ametryne 4 lb. per acre in the center compared to untreated cK at left. Center: Papaya herbicide test. Note at left, Diuron used at 8 lb. per acre; note at right, untreated control area. Right: Papaya. When weeds are not controlled in papaya, plants become unthrifty, disease sets in and death occurs. Note vigorous trees at rear where weeds have been controlled by chemicals.

7 SOIL AND HERBICIDE PHYSIOLOGY

SOIL FACTORS PERTINENT TO CHEMICAL WEED CONTROL[1]

R. E. Green[1]

If one word were to be used to characterize soils in Hawaii, the word "variable" would be appropriate. Although Hawaiian soils are all derived from lava and ash of similar chemical composition, differences in rainfall, temperature, drainage, and age have resulted in widely different soils over relatively short distances. Under rain-forest conditions the weathering is so rapid that one can seldom determine, for older soils whether the parent material was lava or ash. On leeward slopes approaching the ocean, where low rainfall conditions prevail, there appears to be little change in the lava which covered the land several hundred years ago. More recent ash deposits in relatively dry regions have weathered extensively because of their small particle size and associated high surface area. Accompanying the widely different degrees of weathering and resulting mineralogies are a wide range of organic matter contents. A more detailed description of organic matter will be covered by Mr.Suehisa.

Hawaii is certainly not unique in its soil variability. High temperatures and widely different amounts of rainfall over short distances are characteristic of much of the Asian-Pacific area. Since soils are not inert, but provide chemically and biologically active environments for added chemicals, we should all be concerned with soil variability. In general, tropical soils are less fertile than temperate-region soils due to the loss of nutrients through rapid weathering, but they are more reactive in terms of their capacity to immobilize and degrade applied pesticides. Although numerous soil factors are important to plant growth and thus are pertinent to weed control, I will restrict my present discussion to the principle factors affecting the concentration of herbicide in the soil solution and herbicide transport to the plant root.

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HERBICIDES IN SOILS

Soil-applied, pre-emergence herbicides generally reach the soil in aqueous solution as a low volume spray. If the sprayed herbicide is not incorporated mechanically or moved into the soil by irrigation or rainfall it may remain on the surface, especially under dry conditions. In order to simplify a description of the soil-herbicide system, let us presently consider the herbicide to be uniformly distributed in a shallow surface layer of soil, perhaps 5 cm deep. We are primarily interested in knowing what happens to the herbicide in the soil, that is, what pathways of loss or immobilization affect the efficiency of a chemical as a herbicide. A diagramatic description of herbicide equilibrium in the soil-plant-water system is shown in Figure 1. At the center of the whole system is the "chemical in solution"; this phase is the fraction that plants can absorb through roots or through the emerging hypocotyl or epicotyl. Studies to determine the phytotoxic concentrations of herbicides in solution with young seedlings of important crop and weed species are basic to an understanding of the variable effects of different chemicals on different soils. If we know what concentration of each chemical is necessary in the soil solution to provide adequate toxicity for specific weed species, and if we understand the soil-herbicide equilibrium well enough to predict the herbicide concentration in solution, then we should be able to estimate with reasonable accuracy the required quantity of herbicide to apply for weed control over a given period of time.

In Figure 1, the various pathways of herbicide removal from solution phase or, conversely, herbicide return to the solution phase are shown by the minus or plus signs adjacent to the arrows designating the pathways. The phenomena of most interest for tropical soils are adsorption and degradation, since these represent the processes which are most active in controlling the concentration in solution when a given quantity of herbicide is applied to the soil. Adsorption is generally reversible, as shown in the diagram, so it does not represent a loss of chemical from the system. Degradation constitutes a continual loss of herbicide from the solution phase until the chemical reaches a concentration below the level necessary for effective weed control. The characteristics of adsorption and degradation on Hawaiian soils will be discussed in more detail by Mr. Seuhisa and Mr. Obien, respectively.

In addition to the chemical which is adsorbed on the soil and that which is degraded, some chemical is generally adsorbed (taken up) by the plant. The other two phases, undissolved and leached herbicide, shown by dashed rectangles in Figure 1, are possible avenues of loss or temporary immobilization which vary in importance, depending on the nature of the compound, the soil, and environmental factors.

The disposition of the chemical in the soil, then, is described diagrammatically in Figure 1. The dynamic nature of the so-called "equilibrium" between phases should be emphasized, since under most conditions the system is constantly changing. In fact, the word "equilibrium" can be used here only in a loose sense to describe the dependence of one phase on another in an extremely transient system.

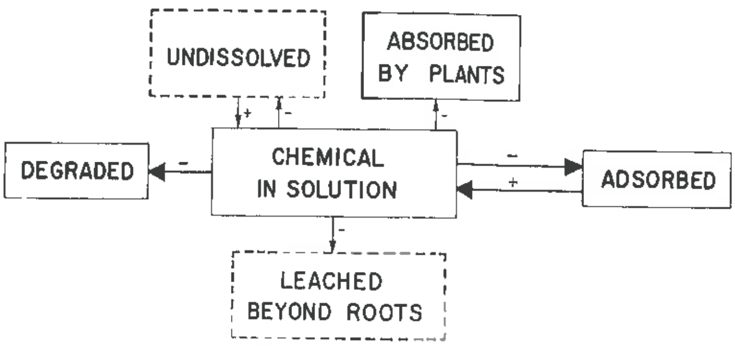

Fig. 1. Herbicide equilibrium in the soil-plant-water system.

UTILITY OF ADSORPTION MEASUREMENTS

Adsorption of organic pesticides in soils can be defined as the accumulation of the chemical at the colloid surface which is in contact with the solution. Adsorbed molecules are in equilibrium with molecules in solution, and a number of factors affect this equilibrium. The mechanism of adsorption is far too complex to discuss here; in fact, it varies considerably for different combinations of chemicals and soil constituents. However, one can obtain a meaningful measurement of the adsorptive capacity of a given soil for a given herbicide without a knowledge of the nature of the forces involved. Aqueous solutions of a herbicide at different initial concentrations are equilibrated with known quantities of soil, and then the post-adsorption concentration of chemical in solution is measured. The amount adsorbed is calculated from the difference between the initial and equilibrated solution concentrations. The results obtained can be plotted as illustrated in Figure 2. The plot of adsorbed chemical against concentration in the equilibrated solution is called an adsorption isotherm (that is, measurements of adsorption at different concentration but at the same temperature). In Figure 2 the solid line is a linear isotherm with a slope of 10, or as the diagram shows, 10 units of chemical are adsorbed on the soil for a unit concentration in solution. The dashed line labelled K = 1.0 represents a soil with low adsorption – only 1 unit of chemical is adsorbed at unit concentration in solution. Thus, in this illustration, one soil is shown to have 10 times the adsorptive capacity of another soil. This indicates that the quantity of applied chemical required to provide a given herbicide concentration in solution might be 10 times greater on the soil with high adsorption than on the soil with the low adsorptive capacity. The adsorption measurement, therefore has immense predictive value for new herbicide materials under investigation for use on the wide range of soils encountered in the Asian-Pacific area.

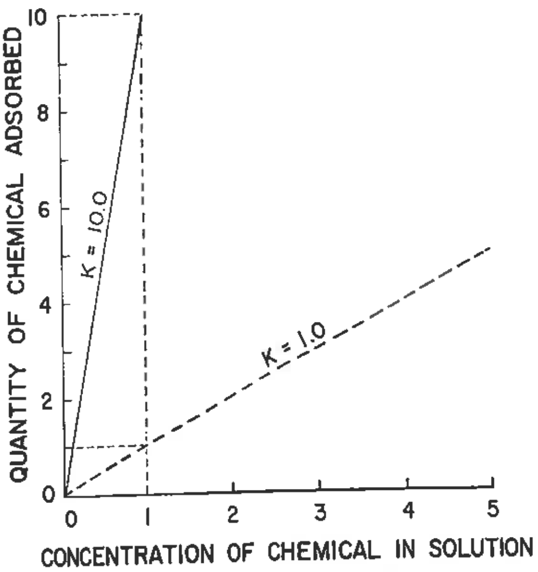

Fig. 2. Linear adsorption isotherms for two soils with different adsorptive capacities. Soils with high adsorption require more herbicide for effective weed control than soils with low adsorption.

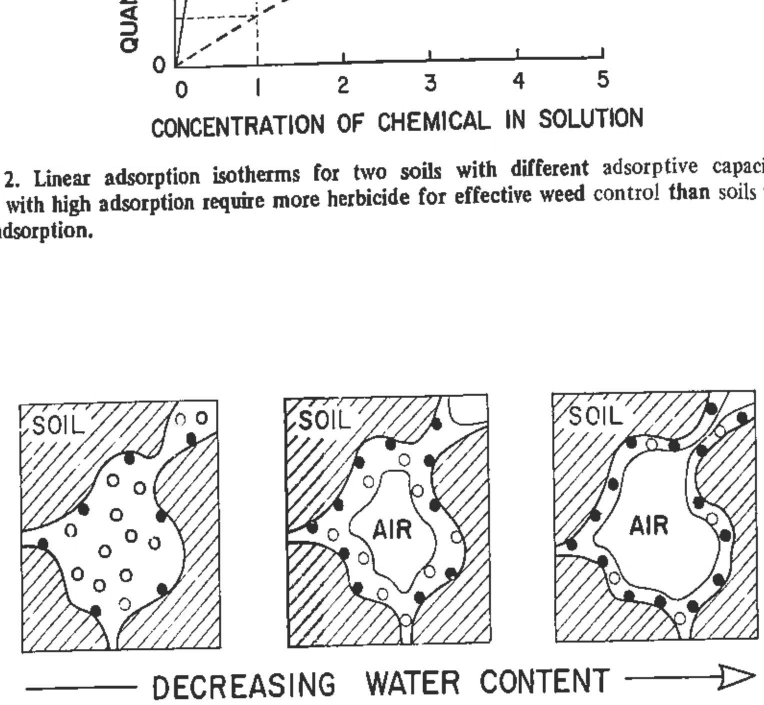

Fig. 3. Herbicide concentration in the soil solution depends on both adsorption and the soil-water content. Black circles represent adsorbed molecules. White circles represent solute molecules.

EFFECT OF SOIL WATER CONTENT

Having some appreciation of the importance of adsorption, we can go on to investigate the effect of variations in soil water content on the availability of soil-applied herbicides for uptake by plants. Consider first the effect of soil water content on the concentration of herbicide in the soil solution. Figure 3 shows three diagrams of the same soil pore at three degrees of wetness – saturated at the left and nearly empty at the right. The solid black dots represent adsorbed herbicide molecules and the open circles represent herbicide in solution. As the soil dries, the total number of molecules in the system (adsorbed plus solute) stays the same, but the volume of solution decreases. The decrease in solution volume is accompanied by an increase in concentration which, according to Figure 2, would cause an increase in the amount of herbicide adsorbed. This process is illustrated by an increase in the ratio of dots to circles going from left to right in Figure 3. If the soil has a high adsorptive capacity the change in solution volume with drying will be accompanied by a small change in solution concentration, since the "excess" molecules are adsorbed. If there were no adsorption, the solution concentration would be inversely related to water content. This qualitative description of the effect of adsorption and water content on the concentration in solution can be expressed quantitatively as follows:

$$C = Q/(K+W)$$

where C is the herbicide concentration in solution, µg herbicide per g solution:

Q is the quantity of herbicide applied, µg herbicide per g soil;

K is the slope of the linear adsorption isotherm;

W is the fractional water content, g water per g soil.

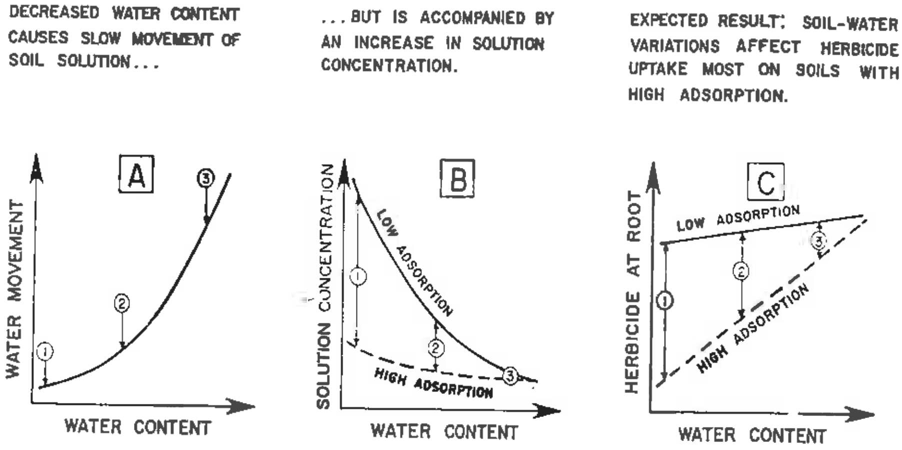

Fig. 4. Expected dependence of herbicide uptake by plant roots on soil-water changes and herbicide adsorption.

For example, if the quantity applied is 5 µg/g, if K has a value of 1, and if the water content is 25 per cent, then the concentration of herbicide in solution should be 4 µg per gram of solution, that is, 5/(1 + .25). Measurements in our laboratory have shown that predictions of solution concentrations based on simple adsorption measurements are quite accurate. The example above illustrates an important point concerning the effect of water content variations: if the value of K is large, variations in W will effect little change in C, but if K is small, variation in W will cause relatively large changes in C. Thus, the effect of water content variations on the concentration of herbicide in solution is dependent on the amount of adsorption.

The concentration of herbicide in solution is not the only factor controlling phytotoxicity. Since the uptake of some herbicides is closely related to transpiration (1), which in turn is controlled by water movement to plant roots, it appears likely that herbicide uptake may be restricted at low water contents when movement to plant roots is reduced. Such an effect has been suggested by the experimental data of Geissbuhler et al. (2). The diagrams in Figure 4 illustrate the way in which variations in soil water content might be expected to affect herbicide uptake by plants. Graph A shows that the rate of water movement increases as the water content increases. Graph B illustrates how the concentration of herbicide in the soil solution is dependent on both the extent of adsorption and the water content. The product of the volume of soil solution moved (Graph A) and the concentration of herbicide in the soil solution (Graph B), gives the quantity of herbicide moved to the plant root (Graph C). The conclusion from Graph C is that soil water content variations may alter herbicide effectiveness more on soils with high adsorption than on soils with low adsorption. Thus both concentration and rate of transport are important factors related to soil water content.

CONCLUSIONS

The wide variation in the soils of the Asian-Pacific area will necessitate a characterization of soil properties pertinent to herbicide equilibria and uptake. Adsorption and degradation of herbicides should receive particular attention. The nature of water movement in soils is important to herbicide movement to roots and will need to be characterized before the effects of water content on herbicide effectiveness can be assessed in specific soils.

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SOME ASPECTS OF ATRAZINE DEGRADATION IN SOILS

S. R. Obien [1]

Herbicides are subject to various avenues of loss when they come in contact with the soil. These losses are mainly due to leaching, erosion by water and wind, volatilization, photodecomposition, and degradation may occur through biological processes carried out by plants and microorganisms, and by chemical processes such as oxidation, reduction, hydrolysis, and hydration. This paper will deal mainly with degradation as it occurs in soils. Several experiments on atrazine degradation are presented here.

Degradation refers to the decay, decomposition, inactivation or decrease in phytotoxicity of a complex material due to structural alteration, and complexing or conjugation with organic-inorganic constituents. Exceptions to this definition are those cases in which the degradation products are as active as, or more active than, the applied parent compounds, as exemplified by 2,4-dichlorophenoxybutyric acid (2,4-DB) in plants and by 2,4-dichlorophenoxyethyl sulfate (sesone) in soils. In plants, the inactive 2,4-DB is beta-oxidized into the active 2,4-dichlorophenoxyacetic acid (2,4-D) compound. Similarly, sesone is hydrolyzed in moist soils to 2,4-dichlorophenoxyethanol, which is further oxidized to 2,4-D. Further degradation of 2,4-D will result in complete inactivation, thus satisfying the above definition.

Data on herbicide degradation are important because they yield information on: (a) length of effective weed control, (b) residue toxicity on crops, and (c) environmental pollution. Studies were therefore undertaken to understand the basic behavior of particular herbicides in specific soil types, and to make some estimates of their activities in relation to crops and weeds.

REVIEW OF LITERATURE

Herbicides known as the s-triazines were first synthesized in the laboratory of the Geigy Chemical Co. in Switzerland. Simazine, which is 2-chloro-4, 6-bis (ethylamino)-s-triazine, was synthesized in 1955 and field tested in the United States in 1956. It was the first triazine to be released for extensive use in agriculture. Another triazine, 2-chloro-4-ethylamino-6-isopropylamino-s-triazine (atrazine), was released in 1958 and has become important in agriculture and industry. Since then, many other triazine herbicides have been introduced for weed control in various crops.

Degradation in plants.

The triazines are generally taken up through the roots, translocated through the transpirational stream to the leaves where their phytotoxic effects are exerted by blocking photosynthesis. Resistant plants such as corn (6,11) and *Coix lacryma-jobi* (6) are capable of metabolizing the triazines into the inactive hydroxy analog. Other plants degrade them by dealkylation or removal of the side chains (13,14). Carbon dioxide is known to be released from the side chain carbons, followed by cleavage of the ring, and again the release of carbon dioxide (11).

Microbial degradation in soils.

Degradation can occur even before the herbicide is absorbed by the plants from the soil solution. If this happens, the concentration of herbicide solution may become insufficient for effective weed control. Conversely, if degradation does not occur, or occurs very slowly, the residue remaining in the soil may damage succeeding susceptible crops.

Triazine compounds are degraded in soils by microbial and chemical mechanisms (4). Some species of fungi were found to grow in culture solutions containing simazine (2); furthermore, it was shown that the fungi made use of the nitrogen of the simazine molecule if a supplementary source of carbon was present in the substrate (5). Evidence of the microbial effect was also shown in the early evolution of $C^{14}O_2$ from ring-labeled simazine incubated in soils (12). Evolution of $C^{14}O_2$ from the side chains, but not from the ring, was also noted in later studies (3,8,9). Hence, it was proposed that dealkylation, and subsequently deamination, was the pathway of simazine degradation in soils (9). This pathway in soils, which differs from the hydroxylation pathway in higher plants (11), was determined from experiments with *Aspergillus fumigatus.* A similar dealkylation mechanism for atrazine has since been demonstrated in mature pea plants, sorghum, soybeans and wheat (13,14). Hydroxyatrazine was not identified as one of the metabolites (13).

Chemical degradation in soils.

Rates of $C^{14}O_2$ evolution from microbial degradation experiments were inadequate to account for rapid decreases in residual activities (15). Alternatively, chemical hydrolysis of simazine or atrazine to the hydroxy-analog was found to be the major pathway of degradation in soils (1,10, 15). Both sterile and nonsterile soils incubated for 3 - 4 weeks yielded hydroxyatrazine which accounted for about 20 percent of C^{14} activity (15). There observations suggest that: (a) microorganisms are not critically important in atrazine hydrolysis, and (b) the formation of the hydroxy-metabolite is the rate limiting step in atrazine degradation. Degradation followed first-order kinetics in soil-free, sterilized soil, and perfusion systems (1).

EXPERIMENTAL APPROACHES TO THE STUDY OF DEGRADATION

Various types of experiments can be conducted to determine herbicide degradation in soils. Some of these are as follows:

1. Measure residual concentrations in sterilized and nonsterilized soils. The herbicide is incubated in sterilized and nonsterilized soils, and the residue is measured at time intervals either by chemical analysis or by a bioassay test.

2. Measure the amount of CO_2 evolved during incubation of the herbicide either from soil or culture solution media.

3. Grow isolated microorganisms in herbicide-treated media and determine their growth, or the change in the herbicide concentrations.

4. Identify metabolites. Extracts of treated samples are analyzed, measured, and identified for possible metabolites by chromatographic analysis, scintillation counting, spectrophotometry, or other techniques. Pathways of degradations may also be revealed through these studies.

5. Study the influences of soil properties. The influences of organic matter, amount of clay, mineralogy, pH, temperature, moisture and other properties can often be determined by quantitatively relating these properties to the measures of degradation outlined above.

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EXPERIMENTS AND RESULTS

Degradation of atrazine is being studied under Hawaiian soil conditions to assess the importance of microbial and chemical degradation mechanisms in relation to soil properties and existing field practices. Atrazine was incubated in solution and soil media, and the residues were measured by using some of the approaches enumerated above.

Carbon dioxide evolution

Atrazine-C^{14} (17.38 ug) was incubated in 30 g Kapaa soil (55 percent moisture) in a tightly stoppered Erlenmeyer flask (500 ml). $C^{14}O_2$ was absorbed by 2N NaOH in a small glass vial placed inside the flask. The data, expressed as ug atrazine recovered within nine days, showed rapid increases in the amount of $C^{14}O_2$ evolved in one to two days (Table 1). The recovery in subsequent measurements gradually decreased to an almost insignificant amount. This result suggests that the $C^{14}O_2$ measurements did not account for increases losses in C^{14} activity (Table 2) which would be expected with time. The two culture systems (A and B) were used to determine the efficiency of collecting samples at different intervals.

Culture Solution

Kapaa soil extracts were added to basal salt media (8) containing 10 and 100 ppm of unlabeled atrazine. Succinate and $NaNO_3$ were used as supplementary sources of carbon and nitrogen, respectively. After 27 days the cultures were filtered through Whatman filter No. 12. The atrazine concentrations in filtrates were measured with a DU spectrophotometer (263 mu). Degradation was highest in the soil extract + basal salt treatment: 6.0 ppm and 17.3 ppm atrazine were lost from 10 and 100 ppm cultures, respectively. The amount of atrazine lost was progressively less with the following additives to the soil extract + basal salt media: $NaNO_3$, succinate, and $NaNO_3$ + succinate. These results indicate that atrazine is a likely source of both N and C for microorganisms in the absence of other sources.

Isolation of Microorganisms

Extracts of Kapaa soil were incubated in sterile agar media containing atrazine. The following fungi were identified: *Penicillium humili, P. chrysogenum, P. spicaria, Cladosporium sp., Mucor sp. Circinella simplex, Trichoderma lignorum, T. viride, Aspergillus sp. and Monocillium sp.*

Table 1. Amount of atrazine (ug) recovered based from $C^{14}O_2$ evolved from Kapaa soil cultures (27 C)

Culture	Days after treatment 1	2	4	5	9	Total	Percent Residual
A	0.172	0.114	0.134	0.015	0.015	0.450	97.41
B	–	0.354	0.155	–	0.031	0.540	96.89

Table 2. Percent atrazine-C^{14} remaining in three soils after incubation (30 C) for 10 and 60 days.

Atrazine: applied: ppmw	10 days Kapaa	10 days Molokai	10 days Kaipoioi	60 days Kapaa	60 days Molokai	60 days Kaipoioi
1	59	79	68	22	39	29
10	64	80	71	24	44	32
50	68	89	77	31	51	33

Degradation in three nonsterilized soils

Atrazine-C^{14} was incubated for 10, 30 and 60 days in four soils. Methanol-extractable C^{14} was measured by liquid scintillation. Data at 10 and 60 days (table 2) show clearly the rapid decrease in C^{14} concentrations with time; the decrease for soils was in the order, Kapaa>>Kaipoioi>> Molokai soils.

The Kapaa and Molokai soils are somewhat similar mineralogically (principally Kaolinite and hydrated oxides of iron and aluminum), but they differ widely in pH and organic matter content, the Kapaa having the lower pH (4.6) and one of the higher organic matter contents (10%). The Kaipoioi soil is derived from ash, contains principally noncrystalline minerals and has extremely high organic matter content (29%) and slightly acidic pH (5.4). The numerous diverse properties of these soils make it difficult to identify relationships between degradation and specific soil properties.

Degradation in Kapaa soil sterilized with gamma radiation.

Kapaa soil was subjected to 3,000 Kr gamma radiation (Co-60), treated with 10 ppmw atrazine, and incubated for 43 days at -10, 30 and 50 C. Nonsterilized soil was included as the control. The results shown in Table 3 are clear evidences that degradation occurred in both sterilized and nonsterilized soils. Furthermore, degradation increased with increase in temperature. In view of the occurrence of degradation under conditions unfavorable for microbial activity, such as sterilization and high temperature, a chemical pathway for degradation of atrazine in the soils is apparent.

Table 3. Percent methanol-extractable atrazine-C^{14} 43 days after incubation in Kapaa soil.

Temperature C	Sterilized (Co-60)	Nonsterilized
-10	86	88
30	30	36
50	10	7

DISCUSSION AND CONCLUSION

Evidence presented in the above experiments, points out both microbial and chemical pathways of atrazine degradation in soils. However, the negligible amount of C^{14} recovered from $C^{14}O_2$ evolution, which decreased with time, and the high rate of loss in extractable C^{14} in soils sterilized by gamma irradiation reveal the chemical nature of atrazine degradation.

The diverse properties of the soils used in the above experiments make it difficult to identify relationships between degradation and specific soil properties. Attempts are being made in our laboratory to study such relationships. Armstrong et al (1) found in Wisconsin that atrazine degradation was dependent on pH; hydrolysis occurred both under acid and alkaline conditions.

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ATRAZINE ADSORPTION BY SEVERAL HAWAIIAN SOILS IN RELATION TO ORGANIC MATTER CONTENT

By Robert H. Suehisa[1]

The close relationship between herbicide adsorption and soil organic matter content has been reported by many investigators (5,8,9,10). However, predicting the extent of adsorption by organic matter content alone has been hampered by the diversity of organic constituents found in soils. It is believed that humified matter forms complexes with inorganic soil materials (3,4). The physical and chemical properties of organo-inorganic complexes differ from organic matter per se.

Organic matter provides sites for herbicide adsorption leading to partial inactivation of the chemical. In cases where the soil organic matter content is relatively high, as in many of our tropical soils, certain herbicides must be applied in larger amounts in order to satisfy the adsorption capacity and yet achieve an adequate period of weed control. Phytotoxicity of a soil-applied herbicidal chemical is closely related to its concentration in the soil solution. Adsorption by the soil removes herbicide from solution and is, therefore, a key factor influencing the effectiveness of herbicides.

Atrazine is a triazine herbicide now prominently used in corn, pineapple, sugarcane, fruit crops, and as an industrial soil sterilant. In recent years, considerable attention has been given to the adsorption and degradation of the triazines in relation to soil properties. Adsorption of this group of herbicides by soil has been clearly established as being mainly due to organic matter. Although the mineralogical properties of soils are important in herbicide adsorption in areas where the organic matter content is fairly low, our attention will be focused on only the organic fraction and the role it imparts in atrazine adsorption.

Twelve surface soils representing a wide cross-section of Hawaiian soils were selected for this study. The organic matter content of these soils is generally higher than in soils found in the Continental United States, ranging from 1.9 to 30.7%. The pH of these soils is generally below neutrality, commonly in the range from 4 to 6.

The atrazine adsorption or distribution coefficient, K_d, was obtained by equilibrating the soils with C^{14}-labeled atrazine solution for 2 hours. The difference in atrazine concentration before and after equilibration was attributed to adsorption. The K_d is referred to as the amount of herbicide (in µg) adsorbed on 1 g of oven-dry soil which is in equilibrium with a 1 µg/ml solution of the herbicide.

Triazine adsorption is an equilibrium process which closely follows the Freudlich equation, i.e., the logarithm of the quantity adsorbed is linearly related to the logarithm of solution concentration. The magnitude of adsorption which is expressed by the proportionality constant K_d reflects the adsorptive capacity of the adsorbent.

It is understood that many factors influence triazine adsorption processes. For example, as the temperature increases, adsorption decreases. Adsorption is also pH-dependent, increasing as the pH decreases. The adsorption process is also influenced by the nature of the adsorbent, i.e., the kind of clay minerals that predominate in the soil. Moisture content may also be important, as herbicide concentration and solubility are dependent on the amount of soil solution.

The relationship between organic matter content and atrazine adsorption of several Hawaiian surface soils is shown in Fig. 1. The correlation coefficient of 0.895 indicates a highly significant relationship considering that the soils are of quite diverse origin. Volcanic ash soils generally contain high amounts of organic matter. Variation in atrazine adsorption in soils having similar quantities of organic matter is probably due to the nature of the organic matter. It may be decomposed or humified to various degrees. The organic matter in many cases may complex with clay minerals, especially in volcanic ash soils, leaving less surface available for herbicide adsorption on both organic matter and clay particles. The Lualualei soil contains predominantly montmorillonitic clay but adsorbed very little atrazine, which apparently reflects its low organic matter content.

Although there have been numerous reports concerning the relationship between

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triazine adsorption and total soil organic matter content, several workers have suggested that only a fraction of the total organic matter is involved in adsorption (6,7). We have so far been unsuccessful in determining only the so-called "active" fraction of the organic matter. Presumably, under practical triazine herbicide application, only a small portion of the soil surface adsorbs herbicide.

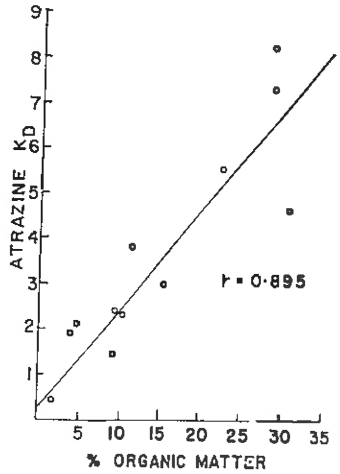

Fig. 1. Relationship between organic matter content and atrazine adsorption of several Hawaiian surface soils.

The variation in atrazine adsorption by Kaipoioi profile samples is shown in Table 1. This soil is ash-derived and contains predominently non-crystalline minerals. Although the organic matter content in the subsoils is relatively high, the K_d value decreases considerably with depth. One would anticipate a high degree of adsorption even in the subsoil by virtue of the high organic matter content, but this was not the case. This indicates the less reactive nature of the organic matter of the subsoils, due possibly to the complex formation between organic matter and inorganic minerals.

Table 1. Atrazine adsorption by Kaipoioi profile.

Depth (in)	Organic Matter &	K_d
0- 3	28.6	7.34
3- 6	15.5	2.30
10-13	24.6	1.74
13-16	26.4	1.36
19-22	23.6	1.52
22-25	21.7	1.58
36-42	19.6	1.45
42-48	19.3	0.89

A relationship between pH and atrazine adsorption of these soils was observed (Fig. 2). Several investigators have reported on the inverse relationship between triazine adsorption and pH (2,8). Adsorption is higher at lower pH, especially below pH 6. Such adsorptive behavior as influenced by pH should be taken into consideration when atrazine application is part of a liming or fertilization program. Lime incorporated into acid soils initially has a pH greater than neutrality until an equilibrium is established. Atrazine applied with lime may be less adsorbed resulting in a higher concentration in the soil solution which in turn may result in unexpected plant injury.

Figure 3 shows the effect of pH on atrazine adsorption in six Hawaiian soils. The Kaipoioi, Kula, and Molokai soils showed dramatic changes in adsorption when the pH was adjusted to various levels. Kapaa and Lualualei soils showed only a slight increase in adsorption with decreasing pH.

Soil acidity apparently influences atrazine equilibria in two ways. First, H-bonding between atrazine and organic matter functional groups such as carboxyls, carbonyls, and amido groups is promoted (11). Secondly, chemical hydrolysis of atrazine to hydroxyatrazine, an inactive analog, occurs. Recent reports have suggested enhanced inactivation of atrazine by chemical hydrolysis in the presence of organic matter and at low pH (1).

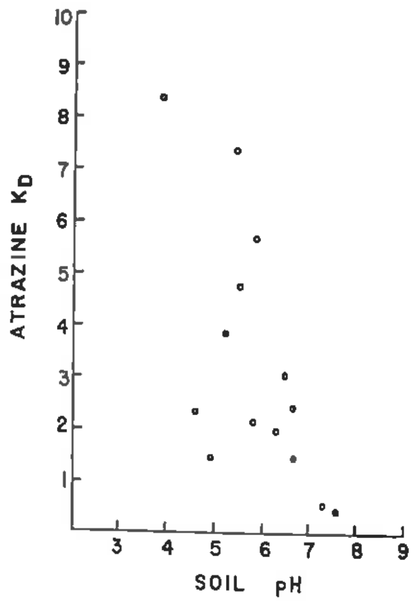

Fig. 2. Relationship between pH and atrazine adsorption of several Hawaiian surface soils.

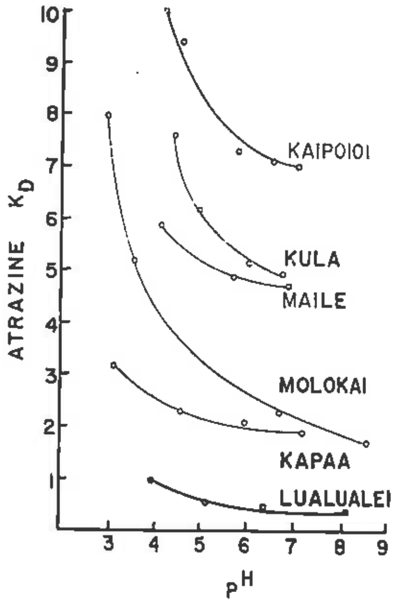

Fig. 3. Effect of pH on atrazine adsorption by six Hawaiian soils.

In conclusion, atrazine adsorption by Hawaiian soils was found to be affected by organic matter content and pH. Adsorption increased as organic matter content increased and pH decreased. These soil factors are of practical consideration when atrazine is included in a weed control program.

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THE EFFECT OF ARSONATES AND PARAQUAT ON NUTSEDGE (*CYPERUS ROTUNDUS L.*) CONTROL[1]

Umporn Suwunnamek and R. R. Romanowski, Jr. [2]

The effectiveness of arsonates and paraquat applied at different times of the day to nutsedge was evaluated from August 1966 to June 1967 at the Manoa and Waimanalo Experimental Farms in Hawaii. The herbicides used in the experiments were MSMA (monosodium acid methanearsonate), DSMA (disodium acid methanearsonate), DMAA (dimethylarsenic acid), paraquat (1:1-dimethyl-4,4'-dipyridylium cation) and aromatic oil (Standard Oil Company 55AR) as the check treatment. The subtreatments consisted of different times of application which were made in the morning (8 to 9 a.m.), noon (1 to 2 p.m.) and evening (5 to 6 p.m.). The application rates of the herbicides were arsonates (MSMA, DSMA and DMAA) 6 lbs. active/acre plus .2% (V/V) X-77 surfactant, paraquat 2 lbs. active/acre plus .2% X-77 and aromatic oil at 80 gallons per acre. The treatments were arranged in a randomized split plot experiment with 4 replications for main plots (herbicide treatments) which were further subdivided into 10 x 10 foot subplots (time of application). Repeat applications were made at approximately six-week intervals from October 13, 1966 to May 28, 1967. The results of the studies are summarized as follows:

1. MSMA was found to be the most effective for nutsedge control when repeated applications were made. The population reduction of nutsedge in the morning and noon treatments was 80% to 85% after 5 applications were made over an 8 month period when compared to the oil treatment.
2. The results obtained with DSMA require additional studies in that the compound gave comparable results to MSMA at the Manoa Campus Farm, but significantly less nutsedge control than MSMA at the Waimanalo Experimental Farm.
3. DMAA appeared to be a promising compound for future nutsedge control studies based on the results from two applications.
4. Paraquat gave comparable control to aromatic oil (check treatment) in the long term effects and this was not considered commercially acceptable.

There were differences between time of day applications with paraquat and MSMA. Evening applications of paraquat resulted in slower regrowth than morning or noon applications. However, the results between time of application were not greatly different when viewed at the end of each 6 week interval. Nevertheless, this observed difference should be explored further in orchard crops which have more shaded conditions. In contrast to paraquat, MSMA was found to be less phytotoxic to nutsedge when applications were made in the evening than in the morning or at noon. The population reductions difference was especially noticeable in the long term effect and it is recommended that MSMA and related compounds be applied whenever possible in the morning or early afternoon of a given day.

Results from greenhouse leaf translocation studies with C^{14}-labeled paraquat and MSMA agreed somewhat with field performance data. There was slightly more basipetal movement of paraquat in the evening treatments than in either morning or noon treatments. On the contrary, MSMA translocation was decreased when applied in the evening as compared to more translocation in the morning and noon applications. No movement to the tubers was observed with either C^{14}-labeled paraquat or MSMA under the conditions of the experiments.

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[1]Based on part of a thesis submitted by the senior author for the degree of Master of Science, Department of Horticulture, University of Hawaii.

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DORMANCY, GROWTH INHIBITION, AND TUBERIZATION OF NUTSEDGE (*CYPERUS ROTUNDUS* L.) AS AFFECTED BY PHOTOPERIODS

G. Berger[1], B. E. Day[2]

Nutsedge, a perennial weed causing great damage to agriculture, has a highly developed underground portion of rhizomes and tuber chains, which in temperate climates remain mostly dormant throughout the year. Ability of nutsedge tubers to remain dormant represents a high degree of adaptation to environmental conditions. Dormancy poses particular problems in weed control, since dormant organs are hard to eradicate by any agricultural means.

Internal and external factors controlling dormancy of nutsedge were studied. A number of growth inhibitors were isolated from foliage and growing tubers, but none from dormant tubers. The major inhibitor, identified as salicylic acid(o-hydroxybenzoic acid), was isolated from foliage, and performed highest growth inhibition. Other isolated growth inhibitors showed less activity and were not studied.

Salicylic acid was isolated from foliage by extractions with 80 per cent ethanol. The crude extract was purified by carrying residues through numerous solvents. Separation of the organic acids was based on partition between aqueous solutions and organic solvents at different pH values. The final acidic residue was further separated by ascending paper chromatography. Identification of the acidic growth inhibitor (salicylic acid) was achieved by the following tests: color reactions with diazotized sulfanilic acid and diazotized p-nitro aniline, ultraviolet fluorescence properties, activation and fluorescence wavelengths, and R. f. values in numerous solvent systems. Relative fluorescence intensity was used for quantitative demonstration of salicylic acid in the extracts.

Bioassay studies were performed that demonstrated growth inhibitory properties of salicylic acid.

Short (10-hour) and long (18-hour) photoperiods were applied to nutsedge. Short photoperiods induced flowering and tuber production, stimulated formation of salicylic acid, inhibited bud growth of tubers, and reduced foliage growth, causing it to grow horizontally. Long photoperiods inhibited flowering, reduced tuber production and formation of salicylic acid, enhanced tuber bud growth, and induced vertical foliage growth.

Salicylic acid is suggested to be the major cause of seasonal dormancy of nutsedge.

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THE PHYTOTOXICITY, SITE OF UPTAKE AND TRANSLOCATION OF DCPA IN RESISTANT AND SUSCEPTIBLE COTYLEDON-STAGE WEED SPECIES[1]

Robert V. Osgood and R. R. Romanowski, Jr.[2]

Dimethyl-2,3,5,6-tetrachloroterephthalate (DCPA) is a pre-emergent herbicide recommended for the control of many grasses and broadleaved weeds in vegetable crops, turf, ornamentals and some agronomic crops grown for seed. In Hawaii DCPA has given excellent weed control in a number of locations, but has been selective on a number of troublesome weed species, e.g., Flora's paintbrush *(Emilia sonchifolia)*, galinsoga *(Galinsoga parviflora)*, swinecress *(Coronopus didymus)*, Spanish needle *(Bidens pilosa)* and jimson weed *(Datura stramonium)*. If the resistant species are present on a farm where DCPA is used, a shift in the weed population to these species can be expected due to their resistance and a lack of other weed competition.

Schuldt and Limpel (1962) reported that it was not possible to predict which weed or crop species would be susceptible to DCPA. In general, however, even those weeds and crops which were susceptible as germinating seeds were tolerant when past the cotyledon stage of development. Schuldt, Limpel and Lamont (1960) stated that DCPA was relatively inert when applied to the foliage of crops making it especially useful for lay-by treatment. McKinley (1965) reported that DCPA did not inhibit the germination of annual ryegrass *(Lolium multiflorum)*, but was highly toxic to the emerging coleoptiles.

Utter (1960) proposed that DCPA was absorbed by the coleoptiles, rather than the roots of emerging grass seedlings. Limpel (1965) confirmed that the major site of DCPA uptake by Italian millet was through the shoot as it emerged through the soil.

Limpel (1965) summarized the translocation studies carried out with labeled DCPA on tolerant crop plants at Boyce Thompson Institute for Plant Research Inc. as follows: When DCPA was applied to the soil, little, if any, was found in the aerial parts of the plants and DCPA remained where applied when placed as drops of aqueous suspension or when dissolved in methyl cellosolve. Crafts and Yamaguchi (1964) reported that DCPA moved only slightly in bean and barley when applied to the foliage. Bayer, Hoffman and Foy (1965)

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studied the absorption and translocation of labeled DCPA in resistant alfalfa and the susceptible parasitic weed, dodder, and found only limited movement of the herbicide in both species. All the literature reviewed has stressed the immobility of DCPA; however, in most of the studies plants beyond the cotyledon stage of development were used. Since DCPA is a pre-emergent herbicide, active after germination but before the emergence of the true leaves, it was proposed that the phytotoxicity, uptake and translocation of DCPA should be studied with plants at the cotyledon stage of development.

MATERIALS AND METHODS

Phytotoxicity studies. A study was made of the effect of DCPA on hypocotyl and root elongation of two susceptible species, spiny amaranth *(Amaranthus spinosus)* and purslane *(Portulaca oleracea)*, and two resistant species, Flora's paintbrush *(Emilia sonchifolia)* and Spanish needle *(Bidens pilosa)*. Seeds were pre-germinated in covered petri dishes on filter paper which was soaked with 5 ml of nutrient solution. Just after emergence of the primary root, 10 seedlings were transferred to each of 5 petri dishes which were lined with a double layer of filter paper. The susceptible species were treated with 1, 5, 10, and 50 ppm of DCPA in 5 ml of nutrient solution, while the resistant species were treated with 1,000 or 3,000, 5,000, 7,000, and 10,000 ppm. Since DCPA is rather insoluble in water (the solubility is less than .5 ppm), applications were made as aqueous suspensions. Each treatment was replicated three times and after the treatments were applied the petri dishes were placed in the dark at 24°C. for 72 hours. In order to assay the phytotoxicity of DCPA, root and hypocotyl measurments of the treated seedlings were made and compared with check treatments.

Uptake and translocation studies. The site of uptake and translocation of DCPA-C^{14} was studied using resistant and susceptible weed species at the cotyledon stage of development. Conclusions were based on interpretation of radioautographs. The species studied were susceptible purslane and spiny amaranth and resistant galinsoga and Flora's paintbrush. DCPA-C^{14} dissolved in methyl cellosolve (having a specific activity of .0285 µc/µl) was applied to the cotyledons, hypocotyls or roots of the above species. One µl of DCPA-C^{14} was applied to the hypocotyl and cotyledon while 5 µl were

Table 1. The effect of DCPA on the hypocotyl elongation of susceptible and resistant weed species.

Species	DCPA Concentration (ppm)	Average Hypocotyl Length (mm)	Percent of Check	Percent Inhibition
Spiny Amaranth	0	19.7* a***	100.0	0.0
	1	12.2 a	61.7	38.3
	5	7.4 b	37.3	62.7
	10	6.8 b	34.4	65.6
	50	5.6 b	28.4	71.6
Purslane	0	11.1	100.0	0.0
	1	8.2	73.2	26.8
	5	6.7 a	60.7	39.3
	10	6.4 ab	57.9	42.1
	50	5.8 b	51.9	48.1
Flora's paintbrush	0	30.2	100.0	0.0
	3000	25.2 a	83.4	16.6
	5000	22.0 a	72.8	27.2
	7000	16.8 b	55.6	44.4
	10000	12.8 b	42.4	57.6
Spanish needle	0	52.2 a	100.0	0.0
	1000	49.5 a	94.8	5.2
	3000	50.0 a	95.8	4.2
	7000	45.0 a	86.2	13.8
	10000	43.3 a	83.0	17.0

*Average value for 30 hypocotyls.
**Means with same letter are not significantly different at 5% level (Ducan's test).

Table 2. The effect of DCPA on root elongation in susceptible and resistant weed species.

Species	DCPA Concentration (ppm)	Average Hypocotyl Length (mm)	Percent of Check	Percent Inhibition
Spiny Amaranth	0	10.3*	100.0	0.0
	1	8.6	83.8	16.7
	5	6.9	67.7	32.3
	10	6.0 a**	58.3	41.7
	50	3.4 a	52.2	47.8
Purslane	0	5.6 a	100.0	0.0
	1	4.9 a	88.8	11.2
	5	4.2 b	76.6	22.4
	10	4.1 b	73.6	26.4
	50	3.3	59.7	40.3
Flora's paintbrush	0	27.0 a	100.0	0.0
	3000	32.3 a	119.6	-19.6
	5000	29.9 a	110.7	-10.7
	7000	29.9 a	110.7	-10.7
	10000	28.7 a	106.3	- 6.3
Spanish needle	0	24.4 a	100.0	0.0
	1000	23.9 a	98.0	2.0
	3000	26.5 a	108.6	- 8.6
	7000	25.6 a	104.0	- 4.9
	10000	26.7 a	109.4	- 9.4

*Average value for ten roots.
**Means with same letter are not significantly different 5% level (Duncan's test).

Table 3. Site of uptake and translocation of DCPA-C^{14} in purslane and galinsoga.

Species	Part Treated	Subjective ratings[1] (24 hours after treatment) Part Rated: Hypocotyl	Cotyledon	Root
Purslane	hypocotyl	****[2]	***	***
	cotyledon	**	****	0
	root	*	*	****
	check	0	0	0
Galinsoga	hypocotyl	****	***	**
	cotyledon	*	****	0
	root	*	0	****
	check	0	0	0

[1]Subjective ratings: 0-no image, *-trace image, **-low image, ***-moderate image, ****-intense image.

[2]Average of four replications.

Table 4. Site of uptake and translocation of DCPA-C^{14} in spiny amaranth and flora's paintbrush.

Species	Part Treated	Subjective ratings[1] (12 hours after treatment) Part Rated: Hypocotyl	Cotyledon	Root
Flora's paintbrush	hypocotyl	****[2]	***	0
	cotyledon	*	****	0
	root	0	0	0
	check	0	0	0
Spiny amaranth	hypocotyl	****	*	0
	cotyledon	0	****	0
	root	0	*	*
	check	0	0	0
	(36 hours after treatment)			
Flora's paintbrush	hypocotyl	****	***	0
	cotyledon	*	****	0
	root	0	0	***
	check	0	0	0

[1]Subjective ratings: 0-no image, *-trace image, **-low image, ***-moderate image, ****-intense image.

[2]Average of three replications.

applied to the roots via the nutrient solution. Four replications were made of each of the purslane and galinsoga treatment while three replications were made of the spiny amaranth and Flora's paintbrush treatments. Purslane and galinsoga were harvested at 24 hours after treatment and spiny amaranth and Flora's paintbrush were harvested at 12 and 36 hours after treatment. After harvesting the plants were prepared for radioautography by separating the plant parts (hypocotyls, cotyledons and roots) so that no translocation could occur during the drying and pressing processes. The dried-pressed plants were radioautographed on non-screen X-ray film for one week. The images were rated subjectively as follows: 0- no image, *- trace image, **- low image, ***- moderate image, and ****- intense image.

RESULTS AND DISCUSSION

Phytotoxicity studies. The data which show the effect of DCPA on hypocotyl and root elongation of susceptible and resistant cotyledon stage weed species are given in Tables 1 and 2. Spiny amaranth and purslane hypocotyls were inhibited by 40% at approximately 1 and 5 ppm, respectively. Greater than 7,000 ppm were necessary to inhibit the hypocotyls of Flora's paintbrush by 40% and Spanish needle hypocotyls were not inhibited significantly at a concentration of 10,000 ppm. Roots of all the species were inhibited less by DCPA than were hypocotyls. Spiny amaranth and purslane roots were inhibited by 40% at approximately 10 and 50 ppm, respectively. Roots of the resistant species, Flora's paintbrush and Spanish needle, were not significantly inhibited at 10,000 ppm. The data show a wide range of tolerance between species and between organs of the same species. Those species which were found to be tolerant in the field were found to be tolerant in the laboratory; likewise, those species susceptible in the field were susceptible in the laboratory. Hypocotyls were found to be more sensitive to DCPA than roots.

Uptake and translocation. The subjective data showing the site of uptake and degree of translocation of DCPA-C^{14} in resistant and susceptible species are given in Tables 3 and 4. Purslane data indicated that all the treated plant parts absorbed approximately equal amounts of DCPA, but the tracer which was absorbed by the hypocotyl moved to the other plant parts more readily than that which was applied to the cotyledons and the roots. DCPA-C^{14} translocation in galinsoga was similar to that which occurred in purslane. The pattern of DCPA-C^{14} translocation in susceptible spiny amaranth and resistant Flora's paintbrush are given in Table 4. In this experiment one group of plants was harvested at 12 hours after treatment and another group at 36 hours after treatment. In Flora's paintbrush, at both harvest times, DCPA-C^{14} was absorbed to the same extent by hypocotyls and cotyledons, however, the DCPA-C^{14} absorbed by the hypocotyl readily moved into the cotyledon while that which was absorbed by the cotyledon moved only in trace amounts to the hypocotyl. DCPA-C^{14} absorbed by the root did not move to either the hypocotyl or the cotyledons. In spiny amaranth DCPA-C^{14} moved in only trace amounts to the cotyledon when the hypocotyl was treated. No movement of tracer occurred when cotyledons were treated and only a trace amount moved into the cotyledon when the roots were treated. Trace amounts detected may be artifacts because one of the control plants produced a slight image on the X-ray film indicating contamination of raidoactivity.

Since susceptible and resistant species in both experiments absorbed and translocated similar amounts of DCPA-C^{14}, it appears that these processes are not important mechanisms of selectivity. DCPA was found to be highly mobile in the acropetal direction when applied to the hypocotyl of all the species studied with the exception of spiny amaranth. Roots were shown to absorb DCPA but very little was translocated to the other plant parts. There appeared to be a a block to DCPA translocation at the point of attachment of root and hypocotyl. It was shown with purslane and galinsoga that DCPA could move freely into the root when th: hypocotyls were treated; hence, there is good evidence for phloem as well as xylem movement.

SUMMARY

The phytotoxicity, site of uptake and translocation of DCPA were studied in both resistant and susceptible weed species at the cotyledon stage of development. Satisfactory bioassays forDCPA phytoactivity were developed using root and hypocotyl elongation as criteria. Hypocotyls of all the species were more susceptible to DCPA than were roots. DCPA-C^{14} was absorbed by cotyledons, hypocotyls and roots; however, translocation to other parts occurred primarily when the hypocotyl was treated. DCPA was quite mobile in cotyledon stage weeds, primarily in the acropetal direction, when hypocotyls were treated but not when roots were treated.

It is proposed that the above soil appearance, before eventual death, of certain dicotyledonous weeds and crops treated under field conditions with pre-emergence applications of DCPA may be the result of hypocotyl uptake with subsequent translocation to the site of action within the plant.

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8 GENERAL PAPERS

THE ROLE OF THE EXTENSION SERVICE IN WEED SCIENCE

Yukio Nakagawa and Yukio Kitagawa[1]

In the relatively new field of Weed Science, the job of the Extension Service becomes increasingly important in (1) correctly interpreting the research results and disseminating these results in such a manner that the farmers and general public will use the herbicides properly to their benefit: (2) reporting the problems encountered in the field with the use of herbicides such as resistant weed species, crop phytoxicity and soil residue problems for research consideration where needed.

In the dissemination of the research results to the farmers and general public much effort must be expended in demonstrating the correct usage of the herbicidal chemicals which require precision application methods for best results.

The following points should be considered in teaching the correct usage of herbicides for their most efficent use:

1. Install demonstration plots at experimental farms and/or private farms and conduct field days or meetings to show the beneficial results of herbicides used properly.

2. Demonstrate proper calibration of application equipment and the importance of precision application of herbicides for best results. This point cannot be over emphasized because precision application of chemicals has not been too critical a factor in the use of insecticidal, fungicidal, nematocidal and fertilizer application with which most farmers are familiar. Most herbicides require very small amounts applied at a proper time uniformly over a given area of adequately prepared soil for good weed control, with a slight overdose causing crop damage and underdose showing poor weed control and waste of money.

3. Demonstrate proper cleaning and maintenance of application equipment to prevent crop injury or contamination from herbicidal residues in the equipment (clean out nozzles and screens, and flush out tank pump and hoses with proper cleaning material and water). It is better to keep herbicide sprayers separate from sprayers used for insecticidal-fungicidal uses especially if hormone type of herbicides are used.

4. Teach growers to recognize the weed species on their farms and to select the proper herbicide for their control. This involves the selection of herbicides registered for use on the crop being grown to reduce the possibility of illegal residues on the harvested crops and also to avoid possible crop damage. Then the herbicide which shows the best control for the weed species present with the least phytotoxic effect to the crop should be selected. For example, on a crop of tomatoes for which both dyphenamid and DCPA (Dacthal) are regisfor use, if the prevailing weed species are those of the solanaceous type, it would be better to use DCPA since dyphenamid will give a poor control of this type of weeds.

5. Make the farmers aware of the importance of small scale test applications of the herbicide intended for use to determine the degree of weed control obtainable and crop phytoxicity under their soil and climate conditions and application technique. Failure to do this may result in a waste of time and money from poor weed control and/or crop damage.

6. Make the farmers aware of the potential hazards from the misuse of herbicides as follows:

   a. Crop damage to neighboring crops from highly volatile hormone type herbicides such as 2,4-D.
   b. Damage to succeeding sensitive crops from herbicides with long soil residual action applied to preceding tolerant crops such as diuron, atrazine, and others applied to pineapples and corn, followed by beans, tomatoes, lettuce, etc., within a short space of time.
   c. Proper mixing and application of herbicides to prevent injury to persons mixing and applying herbicides.
   d. Proper storage and disposal of empty containers and excess herbicidal spray materials to prevent accidental poisoning of children and to prevent contamination of soil, water and air for wildlife and fauna conservation. All full or partially filled herbicide containers without labels or legible labels should be disposed of by deep burial. All empty containers should be disposed of by deep burial and preferably not reused unless effectively decontaminated (for 2, 4-D or other hormone types of herbicides special decontamination treatments are usually necessary). All excess herbicide mixture disposal and spray tank flushing should be done only in one remote non-cropped area away from irrigation canals or natural waterways to reduce contamination of water and soil.
   e. Keep a record of application as to date applied, crop grown and field used on for reference especially if herbicides with long soil residual effects are used to prevent future damage to susceptible crops that may be planted, also to measure build up in soil. After use of herbicides the weed population will most likely change, thereby necessitating the change of herbicide or the mixing of herbicides for controlling the new predominant weed species. This information should be called to the attention of researchers to work on newer herbicides for the control of these species of weeds and for registration for legal use on the crops grown. Soil residue problems, resistant weed species, etc. should all be reported to researchers if research is needed for answers.

Farmers must be made to understand that no one herbicide will control all of the weed species found on most farms, and they must learn to apply herbicides correctly for best results. If herbicidal use is not benefiting a grower, he should be advised to stop use and resort to mechanical or hand weeding.

[1]Associate Specialist and Associate County Agent, respectively, University of Hawaii.

Field day for farmers to observe results of herbicide research on vegetable crops. This field day was co-sponsored by Research and Extension.

INDUSTRIAL HERBICIDE USE SURVEY FOR THE ASIAN-PACIFIC AREA

R. R. Romanowski Jr., W. R. Furtick and R. V. Osgood[1]

Several months before the Asian-Pacific Weed Interchange meetings began, it was decided to survey the world herbicide industry to inventory their present and proposed activities in the area under consideration. An attempt was made to determine the number of personnel engaged in sales and development as well as industries' views relating to the present and future potential use of herbicides. The following three questions were asked of the major companies who are active or intend to be active in the Asian-Pacific area:

1. Number of man years devoted to sales and development work with herbicides in Asian-Pacific area?
   a) 1967
   b) Estimated by 1970
   c) Estimated by 1975
2. Most important factors limiting expansion?
3. Crops on which there is substantial herbicide usage?
   a) At present
   b) Probable in 1970
   c) Probable in 1975

The results of the survey reported in Tables 1 and 2 are enlightening. Twelve major companies reported, representing a fair cross section of world industry. One of the most interesting observations was the number of personnel engaged in sales and development work. The total figures show that the twelve companies are devoting 115 man years to the sales and development of herbicides in the Asian-Pacific area in 1967. Even more impressive are the projected figures of 206 and 292 man years for 1970 and 1975, respectively. Admittedly these figures represent only a few companies, nevertheless, they clearly show the enthusiasm expressed by industry for the potential use of herbicides. The comments presented from industry in Table 1 describing the limiting factors for expansion of herbicide usage are strikingly similar when compared on a company basis. Economics and education stand out as the most important limiting factors. These facts reveal the tremendous impetus which must be given to improving and expanding research, extension and teaching activities by government and private organizations in weed science in the Asian-Pacific area. The limiting factors for expansion imply that agricultural economics, rural sociology and related fields must be called on to assist in developing weed science in addition to the more obvious technical and advisory needs.

The guidelines which can be established by the data presented in Table 2 will undoubtedly be of value in directing weed research programs and related activities. A question was presented to each company asking for a listing of the crops on which there is presently a substantial usage of herbicides and to further speculate on the 1970 and 1975 usage factor. Rice and sugar cane appear to be the two primary crops which are commanding a major portion of today's herbicide market in the Asian-Pacific area. Rubber, wheat, pasture and fruit crops also include a modest portion of today's market as expressed by the reporting Companies. Further growth potentials exist for many crops, but vegetable crops appear to be of major concern. In a sense the data presented in Table 2 are somewhat incomplete; however, data on use factors are limiting for the Asian-Pacific area and this clearly shows the need for well coordinated attempts to improve on statistical compilations for future needs.

It should be noted that this survey was merely an attempt to accumulate general facts and figures which might provide useful information. The most revealing fact was that industry already is actively engaged in expanding the use of herbicides and the immediate future will present many challenges for industry and government personnel to work together to further develop weed science in the Asian-Pacific area.

[1]Associate Professor, University of Hawaii, Professor, Oregon State University, and NDEA Fellow, University of Hawaii, respectively.

Table 1. Number of man years devoted to sales and development in the Asian-Pacific area. (12 companies reporting).

COMPANY	PERSONNEL (Man Years) 1967	1970	Estimated 1975	COMMENTS ON POTENTIAL USE OF HERBICIDES	LIMITING FACTORS FOR EXPANSION
1	7	12	15		a) economics of hand labor b) credit source c) tradition d) equipment
2	10	25	25	Increased herbicide usage will be needed to increase food production in the Asian-Pacific area	a) the cost of herbicides
3	38	50	72	Good potential for use of herbicides in Asian-Pacific area.	a) economics b) education c) cheap labor d) lack of trained persons e) lack of extension
4	1	10	30	Asian-Pacific area is expected to be major growth area for international growth plans.	a) lack of credit b) crop marketing problems
5	3	6	9	If prices for commodities improve there will be increased use of herbicides in Asian-Pacific area.	
6	5	10	15	Increased need for food supplies will result in greater herbicide usage.	a) high cost of chemicals b) small acreages c) lack of education about weed control.
7	7	23	25		a) lack of good extenstion b) lack of tech. knowledge c) lack of incentive to increase production d) foreign exchange difficulties
8	2	5	7		a) toxicity b) cost
9	2	5	10		a) stable world prices lacking
10	1	3	5	Depending on new products for expansion in Asian-Pacific area.	a) high cost of chemicals b) competition from countries where there is a lower cost of production
11	6	9	14		a) clearance of herbicides for new crops
12	33	48	65		a) cheap hand labor except in Japan.
TOTAL:	115	206	292		

Table 2. Number of companies reporting on a crop basis the present and potential use of herbicides in Asian-Pacific area (12 companies reporting).

	No. of Companies			
Crop	Present 1967	Probable 1970	Probable 1975	Total
Cacao		1		1
Coconuts	1			1
Coffee		1	1	2
Conifers		1		1
Cotton		1	1	2
Fruits (general)	1		2	3
1. apple	1		-	1
2. banana	2	1		3
3. citrus	1	1		2
4. papaya		1		1
5. pineapple	2			2
6. strawberry	1			1
Grains and cereals (general)	1	2		3
1. barley		1		1
2. corn	1	1	2	4
3. sorghum			1	1
4. wheat	3	2		5
Macadamia nuts	1			1
Oil palm	2	1	1	4
Pastures (general)	3		1	4
1. alfalfa (lucerne)	2			2
2. clover	1			1
3. brassicas (rape)	2	1		3
Pulses (general)			1	1
1. peanut	1		2	3
2. soybean		1	1	2
Rice	8	1		9
Root crops		1	1	2
Rubber	4			4
Sugar cane	6	1		7
Sugarbeets			1	1
Tea	2	1	1	4
Vegetables (general)	2	4		6
1. potato		1		1

A CHECKLIST OF IMPORTANT WEEDS IN THE ASIAN-PACIFIC REGION

D. F. Saiki, D. L. Plucknett and P. S. Motooka[1]

In order to establish the importance of individual weeds in the Asian-Pacific region, all interested persons and participants in the Asian-Pacific Weed Interchange were asked to list the important weeds of their country or area. Three major ecological areas were separated:

- Table 1. Wasteland, range, pasture and orchard weeds.
- Table 2. Upland crop weeds.
- Table 3. Lowland and aquatic weeds.

Although not all persons responded, the weeds of 17 countries or major areas were presented.

In spite of the fact that this checklist cannot be regarded as complete, it is the hope of the authors that this list can form the basis o, an enlarged and complete checklist for the future. Certainly it should help to identify the more important weeds of the Asian and Pacific areas.

[1]Assistant in Agronomy, Associate Agronomist, Junior Agronomist, Hawaii Agricultural Experiment Station.

Table 1. Wasteland, range, pasture, and orchard weeds.

	Hawaii	Western U. S.	Japan	Philippines	Taiwan	Australia	Indonesia	Thailand	New Zealand	Ceylon	Malaysia	Fiji	New Guinea	Okinawa	New Caledonia	Western Samoa	Cook Islands
Acacia farnesiana	x											x			x		
Artemisia vulgaris			x														
Asclepias curassavica	x															x	
Caesalpinia sepiaria	x																
Cassia tora				x								x				x	
Chondrilla juncea						x											
Cirsium arvensis									x								
Clerodendrum fragrans																x	x
Clidemia hirta	x											x					
Commelina diffusa	x				x	x					x	x	x				
Cyperus aromaticus												x				x	
Cyrostemma calendula						x											
Cytisus scoparius									x								
Echium plantagineum						x											
Elephantopus mollis	x											x					x
Emex australis						x											
Erodium botrys						x											
Erodium muschatum						x											
Eugenia cuminu	x																
Eupatorium sp.	x				x						x						
Hordeum leporinum						x											
Hyptis pectinata												x					
Imperata cylindrica				x		x	x		x	x	x		x		x		
Indigofera sp.	x														x		
Lantana camara	x			x			x				x	x			x	x	x
Melaleuca leucadendra															x		
Melastoma malabathricum	x					x					x						
Mimosa invisa				x							x	x	x		x	x	
Myrica faya	x																
Ocimum sp.															x		x
Opuntia sp.	x													x	x		
Pseudoelephantopus spicatus	x											x				x	
Psidium guajava	x		x										x	x	x		
Rose rubiginosa									x								
Rubus fruticosus									x								
Schinus terebinthifolius	x																
Sida sp.	x														x		x
Solanum torvum												x					
Stachytarpheta sp.	x			x						x	x				x		x
Trichachne insularis	x									x			x				
Ulex europaeus	x								x								
Urena lobata	x											x					
Xanthium pungens												x					
Xanthium strumarium	x																

Table 2. Upland crop weeds.

2

	Hawaii	Western U. S.	Japan	Philippines	Taiwan	Australia	Indonesia	Thailand	New Zealand	Ceylon	Malaysia	Fiji	New Guinea	Okinawa	New Caledonia	Western Samoa	Cook Islands
Ageratuma conyzoides	x			x							x	x					x
Ageratum houstonianum	x											x					
Amaranthus ascendens														x			
Amaranthus hybridus	x																
Amaranthus retroflexus		x															
Amaranthus spinosus	x			x	x									x			
Bidens pilosa	x																x
Brachiaria mutica	x							x			x	x					x
Cenchrus echinatus	x																
Chenopodium album	x	x							x								
Chenopodium ficifolium					x												
Chenopodium murale		x															
Convolvulvulus arvensis		x															
Crotalaria muironata	x																
Crotalaria striata															x		
Cuphea carthagenensis	x											x					
Cynodon dactylon	x	x			x		x						x		x		
Cyperus rotundus	x		x	x	x		x	x		x	x	x			x		
Dactyloctenium aegyptium					x												
Datura stramonium	x																
Digitaria adscendeus	x		x											x			
Digitaria sp.	x		x		x		x			x	x			x			
Eleusine indica	x			x	x		x			x	x	x					x
Euphorbia geniculata	x												x				
Euphorbia hirta	x			x										x			
Festuca arundinacea									x								
Hordeum murinum									x								
Ipomoea hardwickii					x												
Ipomoea obscura	x																
Ipomoea friloba				x													
Lactuca indica														x			
Leptochloa panicea										x	x			x			
Lindernia anagallis				x													
Lindernia cordifolia					x												
Mikania cordata										x	x						
Mikania micrantha																	x
Mimosa pudica	x			x						x	x	x	x				x
Oxalis sp.	x													x			x
Panicum repens	x				x		x	x			x			x			
Paspalum conjugatum	x	x									x	x	x			x	x
Paspalum dilatatum	x			x					x		x						
Paspalum urvillei	x																
Passiflora foetida	x												x				
Portulaca oleracea	x		x	x				x				x	x	x			
Sagina japonica														x			
Setaria pallidifusca												x					
Setaria verticillata	x																
Setaria viridis														x			
Solanum nigrum	x																
Sorghum halepense	x	x										x					x
Stachys arvensis	x																
Stellaria sp.			x		x												
Synedrella nodiflora	x			x													x

Table 3. Lowland and aquatic weeds.

	Hawaii	Western U. S.	Japan	Philippines	Taiwan	Australia	Indonesia	Thailand	New Zealand	Ceylon	Malaysia	Fiji	New Guinea	Okinawa	New Caledonia	Western Samoa	Cook Islands
Ammania coccinea	x	x															
Althernanthera sp.	x				x												
Azolla filiculoides	x						x										
Cyperus difformis	x	x	x	x	x									x			
Cyperus iria			x	x										x			
Cyperus microiria			x		x									x			
Dopathrium munceum	x		x		x												
Echinochloa colonum	x			x			x			x	x	x					
Echinochloa crusgalli	x	x	x	x	x	x	x			x	x		x				
Eclipta alba	x				x												
Eichhornia crassipes	x			x		x	x	x		x	x	x			x		x
Elatine triandra			x		x												
Equisetum arvense			x														
Fimbristylis sp.	x	x		x	x									x			
Glyceria fluitans																	
Glyceria maxima									x								
Hydrilla verticillata							x										
Hydrodictyon reticulatum			x														
Ipomoea aquatica				x													
Ischaemum muticum										x	x						
Ischaemum rugosum												x					
Juncus sp.									x								
Jussiaea prostrata			x														
Jussiaea suffruticosa	x																
Lindernia sp.	x		x		x												
Marsilea crenata				x			x										
Marsilea quadrifolia			x		x												
Monochoria vaginalis	x		x	x	x												
Myriophyllum sp.									x								
Nymphea stellata											x						x
Pistia stratiotes				x						x	x						
Polygonum sp.		x							x				x				
Potamogeton sp.			x						x					x			
Rotala indica			x		x												
Sagittaria sp.	x	x	x		x												
Salvinia sp.			x			x	x			x							
Spirodela polyrrhiza			x														

THE CONTRIBUTION OF THE WEED RESEARCH ORGANIZATION OF GREAT BRITAIN TO TROPICAL WEED CONTROL PROBLEMS

S. D. Hocombe and E. C. S. Little[1]

This is a short review of the overseas component of the work of the Weed Research Organization. The first part gives a general description of the Institute and its functions as regards information, travel and liaison. The second part describes the laboratory research work concerned with overseas crops, weeds and soils. Further information can be obtained by writing to the Director, Weed Research Organization, Begbroke Hill, Kidlington, Oxford, England. Copies are available of the annual report of the Station for those who are interested.

DESCRIPTION AND FUNCTIONS

The Weed Research Organization (W.R.O.) is an Institute of the Agricultural Research Council under the Ministry of Education and Science. It is thus one of the team of research stations controlled by the Council to serve the needs of agriculture in Britain. The Station occupies 288 acres of which some 240 acres are available for experimental work and field scale crop production–in rotation. The Headquarters is in the original 17th century farm buildings. Modern laboratories, glasshouses and other facilities have been added. There is a staff of about 100 of which some 25 are graduates. The technical work of the Institute is arranged as follows:

- Weed Science Department –
  - Evaluation Section
  - Chemistry Section
  - Botany Section
  - Microbiology Section
- Weed Control Department –
  - Agronomy Section
  - Horticulture Section
  - Aquatic Weeds Project
  - Projects on long-term effects of herbicides on soil

Active interest is also taken in overseas problems and W.R.O., like some other Institutes in Britain, receives a substantial annual grant from the Ministry of Overseas Development. This finance supports: a) research into tropical weed control problems, b) the exchange of information, c) correspondence with and personal visits to workers overseas to give advice and, where possible, assistance to workers in countries needing help to tackle their weed control problems.

In many countries the traditional methods of hand-weeding, using relatively cheap labour, are changing. Prices of labour are rising and fewer, people are willing to undertake the heavy work of manual weed control. Moreover, revolutionary advances in crop production methods are possible when herbicides are used. There is an increasing need for the adoption of modern techniques.

As weed control by chemicals becomes more complex with increasing numbers of new compounds and mixtures, agriculturalists in many countries, without as yet elaborate weed research facilities of their own, are realising the need to draw on the assistance and advice available elsewhere. At W.R.O. many of the scientific staff, including the Director, have themselves at times worked in tropical countries on weed research. There is thus a useful stock of experience to draw on when planning and carrying out the work which the Ministry of Overseas Development supports.

INFORMATION AND LIAISON

W.R.O. receives many enquiries by correspondence from all over the world from people seeking advice, comments on proposed experiments (and on their results), literature information, reprints or requests for copies of papers. Many overseas visitors make a point of calling to discuss their work and problems, some for day visits only, others for much longer. A limited number of weed specialists from overseas can be accommodated at W.R.O. to undertake post graduate research work, specialized training or a research project for a higher degree (Ph.D., M.Phil., M.Sc.) at Reading University.

Two international journals on weed control are prepared at W.R.O. Weed Abstracts surveys a large proportion of the world's literature on weed control. It is published by the Commonwealth Agricultural Bureaux, and for its preparation large numbers of journals are taken for scrutiny and many reprints are collected and filed. Increasing numbers of workers from overseas are finding it useful to tap this store of information which is readily accessible through a detailed system of cross-indexing.

The other international journal is known all over the world as PANS. Section C, on weed control, is also prepared at W.R.O., but it is published by the Ministry of Overseas Development. The policy of this journal is to provide up-to-date, readable articles on developments in all aspects of weed science throughout the world. *PANS C* provides not only a source of information to weed research workers everywhere but also a convenient vehicle for publishing the results of their work. Progress reports are welcomed. The journal is additionally popular because the British Ministry of Overseas Development will supply it (and its companion journals Sections A and B on insecticides and fungicides respectively) free to scientific workers in official institutions and educational establishments in developing countries.

There is an overseas liaison officer (Dr. E. C. S. Little) stationed at Begbroke Hill who carries out a considerable programme of travel, which in the last 4 years has taken him to about 40 countries. Journies have been made round Africa, the Caribbean and Central America, and South America. These tours have enabled many people interested in weed research to become more aware of the work being done at W.R.O. and elsewhere both through personal contact and from public lectures given at many places visited. It is hoped that such visits will enable existing contacts to be strengthened and will encourage the development of collaborative research projects carried out jointly by local specialists and by W.R.O.

Reciprocally it has been stimulating for the traveller to see for himself some of the problems that have to be faced and to have the opportunity to establish contacts on behalf of his colleagues in England. It is evident that travel of this type will become increasingly important to maintain and develop the service to international progress in weed science which W.R.O. can give. The next series of visits are planned to include a number of countries in Asia.

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[1]Staff, Overseas Liaison Officer, Weed Research Organization, Oxford, England.

In addition to acting as a liaison centre and a base for the dissemination of generalised information on matters of weed control W.R.O. also produces, as a result of its own research programmes, results which are of direct interest overseas. Many of these results arise from the programme of the Evaluation Section of the Weed Science Department. The function of this Section is to examine the capabilities and properties of the new candicate herbicides which are released by Industry in many parts of the world. The herbicides involved are usually received near the time when the manufacturer first decides to proceed with their commercial development. Approximately 30 new compounds have been received annually over the last few years. The Section carries out experiments both in the field and in the glasshouses and laboratories with which the Orgainzation is provided. The evaluation work carried out in the laboratory and glasshouses has three major objectives. The first experiment with a newly-received compound aims to assess its level of activity when applied in various ways to the root or shoot of six widely different species, two of which are perennials. Promising results here lead to a second phase, in which pre-emergence or post-emergence selectivity is examined over a wide range of annual crops and weeds. In addition there may also be susceptibility tests on perennial species. Over a quarter of the crops and weeds involved in this second phase of the glasshouse programme are of tropical or sub-tropical origin. The third major aim of the programme is to find out the influence of environmental factors on the performance of new herbicides, so that the behaviour of these chemicals in future field trials may be predicted or interpreted.

The techniques used in the early part of the evaluation process are now well established so that this work is on a routine basis. Where possible the results are recorded directly onto punched cards and analysed by computer. Techniques for the third phase are in many cases still under development, but it is intended, eventually, to reduce them to routine procedures.

The relevance of this evaluation work to problems of tropical weed control can be judged from the fact that the 50 or so species involved in the glasshouse selectivity tests include maize, sorghum, rice, cotton, groundnut, pyrethrum, tobacco, *Eleusine indica, Digitaria sanguinalis, Eupatorium odoratum, Portulaca oleracea, Cyperus rotundus* and *Cynondon dactylon.* The 28 species involved in the newly-developed susceptibility tests for perennial weeds include the two perennials listed above, together with *Cyperus esculentus, Digitaria scalarum, Pennisetum clandestinum, Imperata cylindrica, Sorghum halapense* and *Oxalis latifolia.*

In addition to providing those working overseas with information on the reaction of these particular species to many new herbicides the Evaluation Section also produces information which is of value to workers alike in temperate as well as tropical climates. For example, information on the relative activity of a new herbicide when applied to the root or shoot of the growing plant, on the effect of placement at different positions in the soil, or on the rate and pattern of herbicide leaching in response to different infiltration rates comes into this broader category. Some work has also been done to establish the general relevance of principles which were initially worked out from data obtained under temperate conditions. Thus the relevance of much of the work done by the Chemistry Section of W.R.O. on the adsorption of herbicides by soils was widened by the inclusion of several East African soils in the programme. It was confirmed that the same relationship between organic carbon content and adsorptive capacity which exists for many temperate soils also existed for this selection of tropical soils (Hance, 1965).

As soon as possible after they are obtained the results of standard activity and selectivity tests carried out by the Evaluation Section appear in W.R.O. Internal Reports. These reports are intended to provide other W.R.O. Sections with data from which to plan their own programmes, but are also sent to a number of herbicide specialists in other Official research organizations. These include workers in Israel, Canada, Australia, New Zealand, The Gambis, Nigeria, Tanzania, Swaziland, Kenya, Sambia, Jamaica, Trinidad, Mexico and Malaysia. Internal Reports are not formal publications, but selected aspects of the evaluation work may subsequently be summarized in formal papers (e.g. Holly and Holroyd, 1963; Holly *et al* 1966; Hocombe *et al*, 1966).

The suggestions for field trials included in W.R.O. Internal Reports continue to provide co-operators overseas with a source of independent information for use in planning their trials. In addition, the first W.R.O. report on a new compound includes the manufacturer's address and a summary of the manufacturer's own trial suggestions.

As well as sending early results to co-operators on a 'not-for-publication' basis the Evaluation Section of the W.R.O. attempts, either through direct contact or via the Overseas Liaison Officer, to obtain, the results of the co-operator's subsequent trials in exchange. W.R.O. data are also exchanged with groups in the U.S.A. and Europe who are running similar glasshouse and field evaluation programmes with new herbicides. In this way a dossier of information—much of it not yet published—is collected about each new compound, ensuring that at up-to-date picture is always available.

The Overseas Officer of W.R.O. has also been able to take part in some research on problems with an overseas interest. This work has included studies involving new methods of applying herbicides from the air, in narrow precisely defined bands, as a method of treating weeds in water channels with minimum drift and without the need for additives (Little, *et al.,* 1964; Robson, *et al.,* 1966; Robson, 1966). These methods which have been developed in collaboration with the Tropical Pesticide Research Unit could also be used for the application of molluscicides.

In the glasshouses at Begbroke Hill the overseas officer has carried out some important tropical water weeds such as water hyacinth *(Eichhornia crassipes), Salvinia auriculata,* and water lettuce *(Pistia stratiotes).* This work has emphasised the need for those who are troubled with these weeds on important water storage areas to estimate the loss in water caused by them and thus to judge how much effort and money should be spent on their control. The water content of these species has also been studied as a contribution to their assessment for possible utilization. The results have been published in PANS C (Little and Henson, 1967).

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ASIAN PACIFIC WEED CONTROL INTERCHANGE – WORKSHOP

Recommendations from the Workshop held June 22nd., 1967 on the improvement of Weed Control in the Pacific area. K. Newton, Chairman.

The Workshop recommends that:

1. The Asian Pacific Weed Science Society be formed with the object of promoting a free exchange of technical information on weed control problems in the Asian Pacific area.
2. A survey be made of all territories in the South Pacific Region with the object of providing information on major crops, crop areas and crop economics, major associated weed problems, current weed control research, and the potential for use of herbicides on an economic basis.
3. An approach be made to agencies such as the East-West Center, Food and Agriculture Organization, United Nations Development Programme and the University of Hawaii, requesting assistance in the appointment of a specialist or a post-graduate student to carry out this survey and that industry be invited to support this request.
4. Administrations in the South Pacific be requested to designate for each territory an officer who will be responsible within the territory for cooperation with the South Pacific Commission and an Asian Pacific Weed Science Society on technical assistance and clearing house activities.
5. The East-West Center, in cooperation with the South Pacific Commission, organize at the extension officer level, a weed control training programme in the South Pacific Region in 1969.
6. The East-West Center, in cooperation with the South Pacific Commission, assist territories, on request, with the training in Hawaii of weed control personnel.
7. Territories in the South Pacific Region give consideration to the extra curricula training in weed control of students who are studying at agricultural schools and colleges either inside or outside the region.
8. The Asian Pacific Weed Science Society in cooperation with the East-West Center examine the feasibility of the publication of an Asian Pacific Weed Science Newsletter.

WEED PROBLEMS OF PAPUA AND NEW GUINEA[1]

D. R. Petty[2]

On an agronomic basis the present crop culture of the territory can be divided broadly into lowland crops - coconuts, cocoa, rubber, robusta coffee and peanuts and highlands crop - Arabica coffee, with emphasis being towards further diversification. Tea is grown on a plantation scale, pyrethrum by indigenous farmers on small blocks, while essential oils and pasture expansion are being investigated.

WEEDS IN MAJOR CROPS

Weeds of economic importance associated with the major crops are as follows:

Copra. - *Imperata cylindrica*
Mimosa invisa MART
Mimosa pudica LINN
Passiflora foetida LINN

Probably the greatest problem is regrowth of *Imperata* on newly cleared land. Although Dr. Barnes and Dr. G. Watson showed some informative slides yesterday concerning control of vegetation under coconuts, they emphasized the "clean weeding" or weed elimination method of weed control, whereas our present economy must rely on the concept of suppressing weed growth sufficiently to justify cost and would thus involve basal application only. Under the high rainfall and temperature conditions encountered neither 2,2 DPA nor paraquat have sufficiently long effect to be an economic proposition.

Cocoa - *Imperata cylindrica*
Paspalum conjugatum
Leucaena leucocephala (glauca)

Control of *Paspalum* can be effected by paraquat but depending on season the rapid regrowth often renders the treatment uneconomical. The *Leucaena*, used as a shade crop in young cocoa, needs to be thinned and removed as the canopy closes. Varying results using 2,4,5,-T have been

[1] Presented in a Panel Discussion: "Some important problems which need immediate attention in weed control in areas of the South Pacific".

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obtained with frilled cuts but a more reliable procedure needs investigation.

Rubber - *Mimosa invisa* MART
Mimosa pudica LINN

Basal application is again the only economic herbicidal practice possible and use of paraquat has been practiced to some extent.

Peanuts - *Portulaca oleracea*
Euphorbia geniculata
Tridax procumbens
Cleome viscosa
Eleusine indica
Brachiaria reptans

Because of preferential trade agreements this is the only crop presently grown in New Guinea where economics warrant a pre-emergent and total coverage post-emergent herbicide technique. The economically most important species are *Portulaca* and *Euphorbia*. Some success has been obtained with CIPC, linuron and the substituted triazines, however variable the rainfall and soils, particularly the former, have produced such a variability of results that no specific recommendations have been made.

Arabica Coffee -
Paspalum conjugatum
Paspalum longifolum
Cynodon dactylon
Echinochloa crusgalli
Eclipta valerianiflora
Amarathus blitum
Commelina sp.

Although clean cultivation is the ideal, economic considerations are limiting because it takes repeated application of 2,2-DPA to remove the perennial grasses and causes a population shift to *Commelina* and broadleaved weeds. Pre-emergent trials using a wide range of substituted triazines and ureas have produced encouraging, though varying, results because of rainfall variability.

Control of *Pteridum sp* and *Sida sp* in pasture by chemical means has not been attempted because to date pasture management has proved adequate.

Although *Lantana sp, Eichhornia crassipes, Opuntia spps.*, and *Psidum guaava* have been declared noxious plants they have not as yet become major economic problems as they have in other islands of the Pacific. Finally, our most rapidly spreading weed, and one which still requires considerable research throughout the world, is *Trichachne insularis*, which will become a major problem in both improved and unimproved pastures.

WEED PROBLEMS OF FIJI [1]

N. P. Patel [2]

One of the most important problem weeds in Fiji is *Cyperus aromaticus;* locally known as Navua Sedge.

Cyperus aromaticus is a major problem in pastures. This weed is spread mainly by cattle, farm machinery and implements. Loss is not serious in cultivated land because rotation of rice with other crops makes control effective. Cultivation also destroys this weed and gives good control, but it is an expensive method. Cultivation can not be carried out on hilly land where most of the pastures are established. Digging and burying clumps of the weed by manual labor is effective but very expensive.

Regarding chemical control, many chemicals have been tried but none of these have given 100 per cent control. Generally, chemicals kill above-ground parts but re-growth occurs from underground parts. Soil residual herbicides have also been tried, but they do not give complete eradication. When soil residual herbicides are applied they kill both pasture grasses and *Cyperus aromaticus*, and as pasture grasses are slower to recover than *Cyperus aromaticus* the problem of its control comes up again.

[1]Presented in a Panel Discussion: Some Important Problems Which Need Immediate Attention in Weed Control in Areas of the South Pacific.

[2]Weed control officer, Koronivia Research Station, Department of Agriculture, Nausori, Fiji.

The main crops of Fiji are sugarcane, coconuts, rice, bananas, root crops (Dalo, Tapioca) and vegetables.

The major weeds found in Fiji are:

Psidium guajava	Linn.
Clidemia hirta	(Linn.) D. Don.
Urena lobata	Linn.
Mimosa invisa	Mart.
Acacia farnesiana	Willd.
Xanthium pungens	Walker
Elephantopus mollis	H.B.K.
Solanum torvum	Swartz
Lantana camara	Linn.
Hyptis pectinata	(Linn.) Poit.
Sorghum halepense	(Linn.) Pers.
Ischaemum rugosum	Salisb.
Ageratum conyzoides	Linn.
Cyperus rotundus	Linn.
Cuphea carthagenesis	(Jacq.) Macbr.
Mimosa pudica	Linn.
Paspalum conjugatum	Berg.
Echinochloa colonum	(Linn.) Link
Setaria pallidifusca	(Schum.) Staff and Hubbard
Brachiaria mutica	(Forsk) Stapf.

Some of the above listed weeds are serious on cultivated land and some of them are found in pasture land.

The cost of labor varies from F.£0–2–2/hour to F.£0–3–5/hour. i.e. F.£0–17–4/day to F.£1–7–8/day. Labor costs are high and as a result chemical weed control is becoming more popular among Fiji farmers.

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