THE BAWDEN MEMORIAL LECTURE

This lecture is arranged under the auspices of the British Crop Protection Council in memory of the first President of the Council, Sir Frederick Bawden.

THE IMPORTANCE OF WEEDS IN WORLD FOOD PRODUCTION

by

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In an earlier time in my country we had a ventriloquist with a delightful pair of puppets. One was bright and quick, but it was the role of the other, Mortimer Snurd, to be dumb-witted. When the questions were serious and his answers slow in coming he would excuse himself by saying that he had been "thinkin' into the wind". I wish to tell you what we are to do this morning, some of it will be heavy going, and I hope that we may all be "thinkin' into the wind" about our work and the life ahead.

You have asked me to come here to speak about the importance of weeds in world food production. The great generalizations about weeds have been repeated often, and I have therefore chosen to discuss and to show you some particular things which take place down between the bunds and the fences, in the fields and paddies where farmers meet the weed problem. We will discuss crops, animal losses and injuries, and a tragic story of weeds and the loss of human life. We will see some characteristics of weeds which are rarely discussed. I intend that we shall close with a look at the way ahead for it is certain that there will be much change. I hope that the timekeeper will be merciful.

We are to address ourselves to a human activity, agriculture, and the weed vegetation which becomes our companion whenever we put seeds into the soil. Whether on steep slopes of arid rocky soil, submerged paddies, brushy pastures, or level, fertile plains, our priesthood of weed workers is asked to perform the miracle of removing one, or some, green plants from the presence of others.

Our only other way of getting food, now that hunting is finished, is from the world's fisheries. They provide about two per cent of our diet across the world and the harvests have been declining for the past several years.

The agriculture we speak of, outside of forestry, is almost wholly devoted to food-getting. The tonnage of all the cotton, flax, the fibers from hemp, jute, and coconuts, the hard fibers from sisal, and the natural rubber, all this is equal to only 20 per cent of the sugar cane harvest of India alone.

It is an agriculture which lacks direction and leadership for the human family so that we stumble on between regions - and years - of feast and famine. It is so because it is pulled from its course by economics at times, by the politics of aggression and war, by drought, flood, and cold, and always, everywhere, it suffers from lack of funds. Dr. Boerma, the recent Director General of FAO, said before he retired from his post (and I shall paraphrase this to give you the meaning), "One thing that has been harshly, even humiliatingly, made clear in the past 2 years is that with all our scientific achievement and the investment of all our buoyant hopes in a Green Revolution - our harvests are still at the mercy of the weather. In the name of reason how long can the world go on enduring a situation in which the chances of decent food for millions of human beings may simply depend on the whims of one year's weather" (Boerma, 1973).

He was speaking of the importance of man's most essential activity - agriculture.

In some places it is tradition bound beyond all reason, in others it is full of high achievement, but there are also dimensions of mysticism. I show you here a small offering of rice, wonderfully decorated and placed in the newly ripened grain before hervest as a tribute to the Gods. The gift was saved from the last harvest to bring continuity to the most important activity - food-getting - in the lives of these people on a small Indonesian island. I stand in awe of these people and this act, for these were among the best crops I have seen in the world, yet the agriculture is completely primitive. Your God may be dead but He is a viable force in the life of this people.

An agriculture which produces most of the world's food in the warm regions between 23° North and South, where most of our people live, with primitive methods that bring low yields, and where tremendous human energy and sacrifice are required to bring each crop through. In the temperate zone, meanwhile, we have honed our technology to the point where we must pour 10 calories of fossil fuel energy into the food system for each single calorie of edible food we put on the table (Steinhart and Steinhart, 1974). We may have created a monster of machinery which the world will no longer support.

An agriculture in a civilization of such high technology that it can send a man to walk on the moon, while a total land use area the size of Latin America remains in shifting cultivation (Moody, 1975).

It is an agriculture which can hold twice as much of the world's land in pasture as in crops and yet provide most of her people with only five per cent of the protein in their diet from animals (FAO, 1964-1966).

An agriculture in a world of mixed values, in which when airborne we have routine procedures enabling three or four young ladies to feed 100 people a complete meal and clear away the dishes, all within an hour, while flying into or out of the richest or poorest countries of the world. But we have not mastered the means of providing the necessary meals for those who are earthbound.

In this strange milieu of human activity, and under all of these conditions, we are expected to practice a kind of witchcraft which will remove one species or variety of green plant from another - wild rice from rice, or wild oats from other small grains. We must then explain it in terms that even the simplest farmer can understand, and finally exhort him to use our magic.

Before we discuss weeds and our work, in order that others may not think us naive, may I place into the record two matters which have more influence on agriculture and our work than all else we shall discuss:

1. All that you and I can do with our head and our hands is to buy the time needed to supply the world with food. Population control will have to come. In 1950 Latin America and North America, for example, had roughly equal populations. The population growth rate of four of the large Latin American countries is three per cent per year, which means their population will increase nineteen fold within 100 years if this continues. Had the population of North America increased at the same rate since 1950, all food now exported from that continent would be required for its own people and it would be struggling for self-sufficiency. Instead, during 1975 that continent exported enough grain to feed 600 million people, which would be all of the people of India (Brown, 1975).

2. Secondly, there is never enough money - capital we call it - for the bare necessities of agriculture: seed, some fertilizer, some pest control, and perhaps irrigation water. The Center for Population Studies at Harvard University has estimated that the capital investment needed to optimize the agriculture of Africa, Asia, and South America and thereby produce the food needed by A.D. 2000, would be 700 billion dollars (Revelle, 1976). Is it possible to have such a sum for use over the next quarter century? In 1973 the nations of the world together spent, <u>in one year</u>, 240 billion

dollars for armaments. From 1960 to the mid-1970's the nations of the world had already spent 4000 billion dollars for guns (Sivard, 1974).

There is never enough capital for agriculture.

Science begins with the belief that the world is orderly. Or better still, as one of your countrymen, Jacob Bronowski, would put it, " - it can be made orderly by human arrangement". These are some of the things that we, here, have yet to put in order.

First, the small-holders. For a great part of the tropics where there is sufficient rainfall the farms are less than two hectares. In these same areas we find much of the shifting cultivation which I alluded to earlier. As one observes these farmers across the world there seems to be a sort of constancy about their system, it works, it feeds them, and the inputs required are very low. On some sites burning of timber and erosion bring heavy losses but for the most part it works. It is estimated that it feeds 200 million people (Moody, 1975).

These people manage a large part of the world's arable land, their yields are low, but they can be helped. Let us look at the dimensions of their work and their losses.

Table 1

Farmer's time spent in weeding, Western State, Nigeria

(Moody, K. Personal communication, 1975)

Akinlalu village	74%
Idi-Emi village	61%
Ilero village	56%

In Table 1 we may see the amount of time spent just in weeding in the villages.

Table 2

Average per cent crop loss due to uncontrolled weed growth

(From Moody and Ezumah, 1974)

Yams	
West Indies	69
Nigeria	72
Ivory Coast	91
Cassava	
Fiji	75
Venezuela	92
Nigeria	92
Colombia	94
Sweet Potatoes	
West Indies	78
Nigeria	91

If the farmer does not do a proper job of weeding, or it is done too late he may expect the losses shown in Table 2. These are not familiar crops to all of you and lest they seem unimportant I may tell you that they are harvested in greater quantity than the total of all the oats, rye, barley, and peanuts in the world.

Table 3

Effect of weed competition on the yield of crops in Colombia

(Lange, 1970; results of 13 years research data, National Agriculture Research Institute, (ICA), in Colombia)

Crop	Percent yield reduction caused by weeds	
	Range	Average
Rice	30-73	54
Cotton	0-39	31
Corn	10-84	46
Beans	15-88	51
Wheat	0-90	29
Barley	0-63	19
Potatoes	0-53	17

In Table 3 are the losses in seven crops from records kept over a period of 13 years in Colombia

Table 4

Critical periods of weed competition in beans and corn in Mexico

(Nieto et al, 1968)

Duration of weed competition	Percent yield reduction caused by weeds	
	Beans	Corn
10 days	4	2
20 days	22	12
30 days	52	22
40 days	82	48

Many of you, as you see the results of an experiment by Nieto in Mexico in Table 4, may find it easy to say "Oh yes! We all do this routinely today". But have you thought of the meaning in human terms? Nieto reported in Rome that these figures tell us that at any fertility level, for each hectare, the amount of corn lost from weed competition each day was enough to feed 200 people for one day. He was the first of many to help me to realize that in many, many places in the world the size of a man's holding is governed not by the amount of land he can buy, but how much he and his family can plant before they must start weeding. Perhaps this dimension - this measure of a man's world - is the best expression I can give you of the importance of weeds in world food production.

But these losses are straightforward. The reasons for many losses are more subtle and confusing to farmers. If the weeding is not well done, even that which is harvested may be of little value (Table 5). The loss of cowpea seed from insect damage is so much greater in weedy plots that it may account for one-fourth of the farmer's yield loss.

Table 5

Insect damage to cowpea seeds in plots with and without weeds in Nigeria

(From Moody and Whitney, 1974)

	Percent of seeds damaged	
Combined injury from four insects studied	Clean plots	42
	Weedy plots	70

This view of a wheat field up near the Soviet border in Iran is, for you, a strange problem. The large weed patch is a pure stand of Chenopodium album, a weed now much ignored in the Western world. It is, however, one of the most widely distributed plants in the world and is a curse in many cereals. Here, each new seed makes the patch grow larger and the crop harvest less. To handweed it is to pull up or trample much of the crop.

In the 1950s a relative of sugar cane, Saccharum spontaneum, a perennial, ran wild in India on 5 million hectares of rich agricultural land (Timmons, 1952). The infested area was 750 by 1,250 kilometers in size. Farms and villages were abandoned in many areas. The weed is so unpalatable that cattle and goats will not touch it. The average root system reaches to 2 m in depth but some roots have been found at 9 m. I went into the north of the area recently and the weed is still very much in evidence.

But these are examples of weeds on land or in water and we should be reminded that for two decades now weed men have ignored the role of moisture in the weed-crop relationship. I shall put the matter in a question: across all the climatic zones, seasons, and farming systems of the world, is there any single factor of the environment more important than moisture in mediating the crop-weed relationship, as it is expressed in the composition of the weed flora and the flushes of growth which bring pressure to bear on our crop plants? We have time for only one example. Loss of topsoil through erosion may be the greatest permanent loss for agriculture. Weeds, in their relationship with water and agriculture have become the agents for the permanent destruction of large areas of land. One of the countries of Asia has 200 million hectares of arable land and about ten percent of this is in trouble.

In the practice of shifting cultivation, the forests are cleared, the land is used until fertility is low, and until the weed problem becomes unmanageable. Then it is abandoned. The salvation of such land in high rainfall areas is that it must go back to brush and forest with a canopy and litter which will prevent erosion. But often in Asia and West Africa the perennial grass, Imperata cylindrica takes over, prevents the growth of woody species, cannot itself prevent erosion, and so much precious land is destroyed beyond all agricultural use. The ecology of the area is dominated then by a common but terrible agricultural weed which permits the life-giving rain to destroy the area.

When man has fouled his streams, canals, and water bodies through greed, neglect, or the direct introduction of aquatic weeds, it is expected of us as it was of the medicine man, that we will make things right again.

The canal you see here is in Asia and it was built to carry water to food crop lands. The ladies were hired to carry the masses of submerged aquatic weeds to the shore, by hand, while the water is drawn down. Meanwhile, below this point crops, animals, and people suffer for lack of water.

On the far shore of this large bay on Lake Kariba in Southern Africa are many villages where fishermen once lived. The mat of Salvinia molesta, a fern, is permanent. It is 15 cm in thickness, it has excluded all light, and it has destroyed all life beneath. Fishing craft can no longer move on this water. For lack of food the villages have now been abandoned.

Closer to home we may view a food production area in Portugal. These are fields of rice as far as you can see and water hyacinth fills all the canals. This species can cut the flow of water in such canals by fifty per cent. But I show you this to make the point that the crippling of these small arteries is extremely costly to man though it is seldom reckoned as we count our losses in food for a hungry world.

I show you now a view of the White Nile in the Sudan, the weed is again water hyacinth, and it extends as far as one can see across this reservoir of water which is crucial for agriculture. Measurements at several places in the world have shown that evapotranspiration from such an area is four to eight times more than that from a free surface. A photo taken seven years earlier shows that the area was then free of weeds.

But the relation of weeds to our agricultural water supplies may ultimately bring the most serious difficulty through the distribution of seeds of weeds in irrigation water which flows out on our fields and pastures. Bruns and Kelley (1975) in the United States found the seeds of 150 different plant species on the screens of an irrigation canal with uncontrolled weed growth on the banks. This one artery had the capacity to provide 1/10 of a million seeds to each hectare annually.

Weeds may cause the loss of livestock by poisoning, by spoiling meat carcasses and wool, and by causing reduced rates of gain. Australia estimated some years ago that animal losses exceed 100 million dollars annually. In South America, during this decade, 1500 head of livestock were lost in one area because of poison weeds (Furtick, 1970). In sheep country the barley grasses, wild Hordeum species, make it necessary to destroy many animals. I have some photographs loaned to me by Mr. Les Matthews of New Zealand. In the first you may see the infection in the mouth and lips of a lamb. In the second the many seeds are attached to the gums by the awns which have entered the flesh. Another view shows a seed which has entered the eye of a lamb. The last picture shows the foot of a sheep dog with a large sore at the point of entry between the toes, the seed has travelled upward and is now coming out above. The seeds with recurved barbs may continue into the flesh and body cavity and cause infections which bring rejection of large numbers of carcasses at the processing plants.

I have spoken to this conference and written extensively about the role of weeds in human affairs beyond the food-getting activity. I consider the enslavement of much of the human population by weeding tasks, and the social consequences of wasting one's time in such menial labor, to be as serious for the world as losses in food production. I should like to tell of one example of another kind of weed problem about which you hear little but which is of frequent occurrence. It is a story of tragic human suffering and serious loss of food.

I came to Kabul in Afghanistan a year ago to find a deep concern about a continuing epidemic at Herat in the west where there was much loss of life.

Stories reveal that a similar illness, of which one of the symptoms is a distended abdomen, has been prevalent in the area for more than 2 decades. In

1971-1972 a serious drought intensified the incidence of illness and by 1974 the people of the area were calling for help. There were similar outbreaks in 1974 in Madya Pradesh and Rajasthan in India to the south. Many animals were lost as well during these years.

Since 1974 many teams of various kinds, from outside, have gone into Herat. First explanations were of nutrition problems or a possible infectious disease. Now, for reasons too complex to discuss here, most workers feel that toxic alkaloids from the seeds of a Heliotropium species - probably eichwaldii, are causing serious liver damage. The seeds are harvested with the wheat which is not cleaned before being made into flour, and then into bread which provides eighty per cent of their diet. The same alkaloids are known to cause hepatic cancer in animals.

It is again the drier areas that are most seriously hurt, some villages have been abandoned, and generally 20% of the population affected comes down with the liver disease. Mortality is very high, being twenty to fifty per cent for those seriously poisoned.

In sum, the estimate I was given in Kabul is that 3 to 4000 people have died and perhaps 10,000 were made ill from one season's harvest (Copplestone, 1976).

The fruits of the work I have been doing with Prof. Pancho of the Philippines and Mr. Herberger of the United States, and which is now almost finished, have provided some simple, direct insights for the work ahead. This was indeed my objective - to simplify and bring order to a perplexing problem in agriculture. For 15 years we have counted, ranked, and mapped those weeds which are most important, and have tried to bring together most of what is known about the biology of each species. Justice Oliver Wendell Holmes used to tell the new apprentices who came to work with him that "simplicity lies just beyond complexity". After this long period I am privileged, finally, to experience this in my work.

But the above work, we find, has also raised up some of the next questions which man must ask, and this is indeed the way of science. There are bold patterns and subtle inferences that come with large amounts of data arranged so that one may ponder them. We have time for only one of these characteristics of the weed world. As we look at the plant families which give us our weed species, please remember that the words annual, biennial, and perennial have little meaning outside the temperate zone and it is thus not possible to place each species neatly into such categories. Aquatic species are included in some, but not all, of the calculations and tables. The methods we have used and the decisions we have made were described on two previous occasions at this conference and would require a discussion period on their own behalf. For those who have a serious interest and data I would enjoy a discussion far into the night.

First you may view in Table 6 the total number of weed species of concern to man, the plant families, and those of primary and secondary importance.

Table 6

The World's Worst Weeds

-- 206 species important to man
-- in 59 plant families
-- 80 species of primary importance
-- 126 species of secondary importance

In Table 7 you will see the 12 plant families which are most important. These families provide seventy per cent of man's weed problem. More than forty per cent of our weed problem is contributed by grasses, sedges, and members of the Asteraceae. One-fourth of the weeds are grasses and sedges. Forty-seven other families have one or two weed species, a few have three species.

Table 7

The World's Worst Weeds

The Important families

Poaceae (Gramineae)	44 species	27%	43%	68%
Cyperaceae	12			
Asteraceae (Compositae)	32			
Polygonaceae	8			
Amaranthaceae, Brassicaceae	7 each			
Leguminosae	6			
Convolvulaceae, Euphorbiaceae	5 each			
Chenopodiaceae, Malvaceae Solanaceae	4 each			

In addition, 47 other plant families have 3 species or less

In Table 8, you may see something of the relative importance of the species in these plant families. There are several matters of interest here but we may discuss only two. First, it may be of interest to you that the 13 food crops harvested in greatest quantity by man, and which provide three-fourths of his food, with one minor exception can all be found in these same 12 families. Please remember these families give us seventy per cent of the world's worst weeds. The important crops rubber and cotton are also in these families. We must be careful about hasty interpretations of this kinship between weeds and crops, however, for two of the most important families, Asteraceae and Cyperaceae, provide man almost nothing for food, clothing, and shelter. Sunflower seeds from the Asteraceae would rank about thirtieth in man's harvest of crops.

Next, in the primary weeds - that group which is most devastating in our fields and waterways - it is interesting to find that almost 60 per cent of them are in just three plant families.

Table 8

The World's Worst Weeds

Primary and secondary weeds by family

	Primary weeds (80)		Secondary weeds (126)	
Poaceae (Gramineae)	30	58%	14	33%
Asteraceae (Compositae)	12		20	
Cyperaceae	5		7	
Polygonaceae	3		5	
Amaranthaceae	2		5	
Brassicaceae (Cruciferae)	1		6	
Leguminosae	2		4	
Convolvulaceae	1		4	
Euphorbiaceae	1		4	
Chenopodiaceae	1		3	
Solanaceae	1		3	
Malvaceae	1		3	
	plus 18 other families		plus 33 other families	

In Table 9 we may see that almost 60 per cent of the primary and secondary weeds together are annuals.

Table 9

The World's Worst Weeds

(206 species)

57 per cent	43 per cent
are annuals	are perennials

In Table 10, as we attempt to probe with more specific questions, the data begin to include several characteristics of weeds and these cannot be easily assimilated in brief discussion. Let me point out two things. Grasses provide a larger portion than broadleaved weeds for the species which are most serious across the world. Secondly, because so many perennials are among the primary weeds, broadleaved annual weeds, which are so plentiful in the plant kingdom, make up a very large proportion of the secondary weeds.

Table 10

The World's Worst Weeds

	Primary Weeds (80)		Secondary Weeds (126)	
	% which are:*		% which are:*	
	Annual	Perennial	Annual	Perennial
Grasses	18	18	7	4
Broadleaves	33	23	48	17

*Excluding sedges and aquatic weeds

Agriculture is the mother of our work. Her direction will bring our assignments. My comments in the remaining minutes are grounded in the belief that the direction has already changed. If the man who makes the shoes for the farmer declares that his business is only shoemaking, and if the weed man similarly denies any responsibility for the new horizons for agriculture - is it to be so with all parts of agriculture? Who then shall lead us? Who does decide the way we shall go?

If we do not understand where we are now (is our technology already too energy dependent, for example), and if we do not try to estimate where we are going as we try to produce food, then we in weed science will be constantly taken by surprise, we will not know how to establish priorities for our work, we cannot know which weed species will come next, we'll be denied the lead time for solution of problems, and we shall contribute to chaos in the most important of all activities for the family of man - in a world that is already hungry.

The energy shortage is only one ingredient for the new direction but it has quickened in most of us the startling realization that:

- fertilizer costs are suddenly too high
- agricultural chemicals are in short supply and the price is soaring
- fuel costs have doubled and tripled
- we must all ask, ultimately, whether these things will be there at all, even if we have the money to buy them

Many wise men are asking whether all of agriculture must now be re-examined, for the more advanced countries may have created a technological monster that the world will no longer feed, while we have built very little in most of the warm regions where most of the food for the world is produced.

This activity, food-getting, begins each morning at breakfast for every man, and it influences his decisions about security, procreation, and his allegiance to the institutions which touch his life. It is my own view that we may yet see much pushing and shoving among governments, within unions, and between political groups. I hope that families and activist groups may be able to register their priorities and wishes as we allocate the limited resources for agriculture.

May I mention just four of many things that do not often come to the attention of weed men but which will surely be a part of our future in agriculture.

Dr. Helmut Lieth, formerly of Stuttgart, and sometimes a participant in weed meetings here and on the continent, with a colleague at North Carolina where they are both now located, has just published a book on the primary productivity of the biosphere. They have estimated that man's food harvest is still only 0.72% of the net primary production of the world, and his wood harvest is only 1 or 2% (Lieth and Whittaker, 1975). Yet the World Bank estimates that there are 500 million mal-nourished people (Walters, 1975), and ⅓ of mankind must still depend on wood to keep warm and prepare food. How long shall we settle for this?

Grains supply more than half of man's food energy and they occupy more than seventy per cent of the world's croplands. A sizeable additional quantity of energy is supplied by grain products consumed indirectly as meat or processed foods. World grain yields per hectare, excluding rice, increased steadily from 1960 to 1972 during a period in which much publicity was given to the great strides made in crop production - it was called a "revolution". But now world grain yields have fallen for three consecutive years (Brown, 1975).

At the beginning of that period the reserve stocks of grain in exporting countries plus the idle land in the U.S. which could be converted to grain in one year provided the equivalent of 105 days of world grain consumption. By 1974 reserve stocks stood at 26 days, in 1975 they remained low, and you may judge for yourself what the drought in Europe and the grain belt of North America has done to grain production for 1976 (Brown and Eckholm, 1974).

Perhaps you and I ought to begin asking whether life is not too precariously balanced to risk such a large portion of our crop production in one plant family?

Within the lifetime of many of you there has been remarkable turnabout in the production of the world's grains. Before World War II all geographical regions of the world (except Western Europe) were net exporters of grain. Five million tons came out of North America, and also from Eastern Europe and the Soviet Union, while 10 million tons came out of Latin America. Today we have good data on the grain supplies of 115 countries and all but a few now import grain.

Asia alone requires 50 million tons with Japan taking more than any two countries combined. Meanwhile the grain exports from North America have risen to 100 million tons - enough to feed India's 600 million people (Brown, 1975).

There must be a question here for us - we are a part of agriculture. What would a crop disaster in North America mean to the world. It is an area with only one-sixth of the cultivated land of the world. For the good of mankind ought we not help to put some things back into their proper places quickly?

A prolonged diet of cassava, taro, or potatoes soon brings on protein malnutrition. Children grow into adulthood without appropriate amino acid building blocks for brain and body, and they are forever crippled and handicapped. In the Western world we take in seventy to one hundred per cent more food energy than most of the people in the world on average, and we get ten times more of this energy from animal products. Similarly, our intake of protein is about twice that of most of the world's people and we obtain about ten times as much as they do from animal sources. In my own country we obtain forty-five to sixty-five per cent of our protein from animals and excrete half of it.

For all countries with this fanatic devotion to red meat there are tremendous sacrifices in land area that could be used for direct production of food for humans. Animals convert only ten to twenty per cent of the energy in their feed to energy contained in edible food for our tables. In my own country one-third of the best soils are planted to corn and soybeans, ninety per cent of which is used for animals. Much of the rest comes to Europe for animal feed.

Elsewhere in the world only five per cent of the protein in diets comes from animals. Many crops, including soybeans, peanuts, Vigna mungo, the mungo bean, and the winged bean, Psophocarpus tetragonolobus, provide two or three times more energy than red meat while each has a protein content which is equal or better. Certain varieties of the soybean and the winged bean may have thirty-seven per cent protein, almost twice that of red meat.

We must not be confused by the propaganda that only animal protein can supply the balance of the required amino acids. Several combinations of crop plants do this very well. The Kalahari people of the arid lands of the south of Africa know which leaves, fruits, and roots of weeds to add to their maize and other crops, and in the proper season, in order to keep both children and adults healthy. Your own biochemists from Britain have been there to perform analyses which validate the choices of plant material in use by these isolated people (Shanley and Lewis, 1969). Elsewhere, hundreds of millions of people are healthy and are thriving on diets derived almost entirely from crop plants.

Animals have been a threat to man's food supplies from the time he began to domesticate them. Two-thirds of man's agricultural land is now in pasture in the world. Some animals will remain as beasts of burden. Whether you and I understand it or not some will continue, in the face of hunger, as religious symbols in some countries. The shame is no greater, however, than the religious devotion to red meat in developed countries and the excretion of large quantities of the protein. As hunger moves across the globe we must ask ourselves whether production of meat animals will be pushed to the marginal areas for forage so that the harvest from some of our best soils may be used directly for human consumption?

For weedmen, what will the new world be like for the long term ahead? May I try to formulate some of the questions for which we must have answers, in the hope that others who are wiser and taller may refine them and add others which are significant?

We do weed control by crops. About 13 crops now provide three-fourths of the food for all mankind. Eight are in one family. With the dwindling of our food reserves, the changing climate, and the new economics for energy supplies, will there be new crops? As we shift production of large areas of the world's best soils from feed for cattle to food for human beings, what ought the new crops to be? We do weed control by crops.

Only about four per cent of the water from the world's rivers is captured for agriculture before it reaches the sea. We can be sure that more of this will be diverted to irrigation. Whom do you think should raise the alarm and prevent the spread of disastrous weed problems because of seeds in our water sources?

If we may not use herbicides because of the cost and non-availability, what will we do to control weeds? If we count on machines, can we afford the fuel? Will there be fuel that we may purchase? For some areas of the world the answer is "no" for both questions already. Are we going to have to re-think our research and finally have to come to know the biology and ecology of each weed species so well that we can make one very frugal application or treatment with great precision?

If food production amounts to less than three-fourths of one per cent of the primary productivity of the world's entire biosphere, what are you going to do to improve this? Will increased production come on good soils or marginal ones, in humid or arid regions, and will some of it be in aquatic systems. Do you think we know the species of weeds well enough to control them?

There are several changes that all can recognize. We are going to have fewer choices for land preparation, and this is one of the farm operations which has great influence on the weed flora. What are the new species we may expect? Some weed men are still talking about the possibility that weeds may have biotypes, although it has long been common knowledge that we find them in almost every species we examine. We are finally beginning to understand that we have the same problem as the insect and disease people. The shifting ecology of our fields with continued use of herbicides is one of the principal problems in weed work today. I wonder if you are aware that there is not one comprehensive, lucid paper on the principles involved in these shifts and the lessons we have learned from them across the world.

In my view, and I hope that you have one of your own, we have stumbled as scientists, and seemed awkward, as we are besieged by those just beside us who are frightened at the use of chemicals in the world. While the nations of the world are losing one-fourth million lives annually to automobiles, and maiming millions more, our neighbors take us to court and we lose everything - chemical after chemical - sometimes without evidence of the loss of a human life. It seems only necessary to establish that the ecology of an area has changed to weaken the position of an interesting plant or animal. Our reaction is often to become indignant, to fall back on "our facts", to regard such people as light-headed, and to wait for the storm to pass.

But, we are losing!

I do not have simple answers but until we recognize what is happening to us there will be no answers. May I develop one dimension of this problem for a moment? The concern is that we are losing tools - valuable chemicals - that <u>can</u> be used safely and <u>are</u> sorely needed in all parts of the world. Who is to defend them? I have spoken of "our magic". Science is now so complex that understanding fails for many. <u>We</u> are the high priests of science but we are learning that "our facts" do not change minds readily for scientific experts can be produced to testify on all sides of an issue these days.

But we are not alone - and this is not the first time. There are some lessons in the writings of Sir Thomas More, in another time, which have helped me to understand what is going on here. After a brilliant career of public service he became Lord Chancellor, he soon found himself in conflict with Henry VIII, and his life was taken. He was not for sale and so the king determined to bring him down because he would not sacrifice his religious beliefs or twist justice to provide a blessing for the king's problems with his ladies and his heirs. Men were sent to trick and trap him, but the king was clever and he kept them vaguely within the law. The friends of Thomas More urged him time and again to arrest these lackeys and have them put away, for he had the power. He responded by reminding them that they, his associates, seemed to find the currents and eddies of right and wrong very plain sailing, while he found them difficult to navigate. He said, "I am not God". But in the thickets of the law - man's law - he knew his way and he told them he would let these lackeys and the Devil himself go - until they broke the law. When his son-in-law responded that he would cut down every law in England to get at the Devil, More's response was magnificent and it is this very point that I wanted to make because it speaks to our predicament several hundred years later. Let me quote for you from Robert Bolt's play about this wonderful man. "So, you would cut a great road through English law to get at the Devil? And when the last law was down, and the Devil turned round on you, where would you hide, the laws all being flat? This country is planted thick with laws from coast to coast - man's laws - not God's, and if you cut them down, do you really think you could stand upright in the winds that would blow then. (Soberly) Yes, I'd give the Devil the benefit of the law - for my own safety's sake."

In my own country, a nationwide survey of hospitals by a responsible group at Colorado State University has shown that we <u>did</u> have 8000 cases of hospitalized pesticide poisonings among farmers and agricultural workers in three years ending in 1973. In terms of the total workers involved the rate is low but it increased dramatically in those three years. There is speculation that this may be due to replacement of chlorinated hydrocarbons by the more toxic organophosphate insecticides (Savage et al, 1976). We now find ourselves on both sides of the same issue. I can take you to places in the world where young ladies walk through arsenite all day as they spray plantations. We have just concluded a pesticide lawsuit in my country involving the tragic ill health of workers and the pollution of a large watershed by people who should have known better. You will have your own examples from your own countries. When medicines for our ills, improvements for our diets, and toxicity levels for pesticides are worked out with small test animals, we must not be surprised when citizens begin to ask questions about the effects of the same pesticides on the same small animals in the natural environments around them.

We cannot feed the world without wisely using our best tools, but we cannot pretend that our work has been done perfectly. All objections of environmentalists are not "side issues". When the public knows something is wrong but cannot pile up human bodies on the courtroom floor, they must use procedural matters to win points. The vegetation issue in Viet Nam was of help in closing off an unjust war by my own people and the fallout from that controversy still cripples herbicide use. Declining animal populations may be related to chemicals in our soil and water. The change in our values and the knowledge that the air, and water, and soil are finite here where we live - reminds us that we have no place to hide. We must face these issues now. The opposition may know as much about the very long term effects of pesticides on humans as we do - and all this may not be very clearly understood - but so far it is within the law.

It seems to me our role is to build with a steady hand the information needed, to bring our influence to bear within the law wherever we work for the cause of food production, to defend only that which is truly known to be right and just for those who will use it - and to thank God for the laws of England - that we too may have equal opportunity to be persuasive when our turn comes!

Finally, there is the question about bringing modern agricultural methods to smallholders and to developing areas of the world. It is my own view that it is a question which we keep under the table and is seldom addressed openly for agriculture in general or for weed control in particular. Perhaps it is so simply because it is such a complex issue. Some believe that modern methods will bring such unemployment that great social disturbances must follow. It is my own view that weeding in fly-infested fields and ditches for a lifetime is to enslave a human being. He or she has no chance, or a very limited opportunity to go to school and thus cannot enter into the political process, such a person enters adulthood without ever having the time to be creative, and tomorrow - the future - offers little hope for release from grinding poverty for those who must weed fields by hand.

Dr. Nieto of Mexico has helped me more than anyone else with this matter. In his words, "You have to decide, are you going to produce the maximum food for a hungry community, or do you wish just to make busy-work for hungry people. You cannot have it both ways today".

It seems to me we ought to make this decision well, apply our methods wisely by region, and then have the guts and courage to see it through. We must weigh the cost - either way. Let me take an example which is outside our field where we can see this better.

I am speaking of a commitment of science to the service of mankind.

In my country in the mid-1960's we reached a peak in the epidemic cycle of rubella, or German measles, in newborn infants. We closed 1964 with 20,000 cases of blindness, hearing loss, heart defects, mental retardation, and death. The disease was expected to peak again in the 1970's. In five years 55 million children were inoculated with a vaccine and the incidence of the disease was reduced more than seventy-five per cent. It is now estimated that rubella could be virtually eliminated by the inoculation of every child and at a cost of 10 million dollars. The cost of caring for the crippled children who survived the 1964 epidemic alone, is two billion dollars annually - and there are still 20,000 broken lives.

I repeat that we must weigh the costs wisely, and then bring science - also a human activity - boldly and willingly into the service of mankind. If knowledge is withheld simply to fill the days of men and women with field work, and if food production is therefore less, somewhere there will be more hunger. Children who are forever hungry grow up without the building blocks needed for brains, bones, and muscle. This is the worst form of enslavement, and as with the children crippled by rubella, it is for eternity. We must weigh the cost.

I wish to close with a phrase used often by an English lady. Will there be too many people? Will we find the capital neede for agriculture. Will a group such as we have gathered here consent to bring the things we already know into the service of mankind so that we may provide the necessary meals for those who are earthbound. Barbara Ward Jackson would say, "It requires only an act of will".

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BAWDEN MEMORIAL ESSAY COMPETITION

In memory of Sir Frederick Bawden, first President of the Council, the Bawden Memorial Trust makes a number of awards each year to enable young people to attend the British Crop Protection Conference, held annually at Brighton. These awards are made on the basis of an essay competition, open to young people of any nationality studying or employed in Great Britain. The overall winning essay for 1976 is presented on the following pages.

THE STATUS OF CROP PROTECTION IN DEVELOPING COUNTRIES

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"Since those days were, when one came to a heap of twenty measures there were but ten; when one came to the press fat for to draw out fifty vessels out of the press, there were but twenty. I smote you with blasting and with mildew and with hail in all the labours of your lands......" (Haggai 2; 16-17).

These Old Testament verses describe crop losses and a fatalistic attitude towards them, not dissimilar to those of peasant farmers in many parts of the world today. In the 1960's, 42% of the potential value of all crops grown in Africa and 43% of those grown in Asia were estimated to have been lost through attacks by insect pests, diseases and weeds; further losses were attributed to polyphagous pests such as locusts, termites, ants and rodents (Cramer, 1967). Such losses are substantially greater than those suffered in European countries, Australia, New Zealand and the U.S.A., but to reduce them is not just a simple matter of recommending to farmers that they apply more protective chemical sprays to their crops.

Until recently, among most tropical peoples, agriculture was practised mainly for subsistence, and farming habits were intimately bound up with elements of tribal culture. Even now, despite the widespread production of crops for sale, farming in many tropical countries is still in the nature of a traditional occupation rather than a business. Farms tend to be only as large as can be managed by the peasant with the help of his wife and family, using the same crop husbandry methods as did his father before him. In India, the average farm size is $2\frac{1}{2}$-3 ha, and in Indonesia little more than 1 ha (Cramer, 1967). Although methods are often primitive and affect adversely both the quality and quantity of the crop, attempts to introduce improvements meet with strong conservatism and resistance to change.

Agriculture has a heavy burden to bear in most developing countries. Besides having to feed the (usually) increasing population, it has to provide more food, with less labour, to supply the growing numbers of people who are abandoning their traditional occupation to seek employment in the industries developing in urban areas. It has to satisfy the increasing demand for food from the total population, with its improving income and, consequently, greater purchasing power. It also has to produce capital, so that the manufacturing industries may evolve. The economy is very vulnerable during this period, and there is a danger that the move to the towns and the intensification of agriculture become out of phase with each other. Therefore, advice and assistance from more advanced countries in the use of crop protection and other methods leading to higher crops yields is especially valuable. On the other hand, it is now being actively suggested that chemical manufacturing companies should take over the development of agriculture, including the protection of crops in developing countries. Whilst this might be expedient in terms of the speedy production of food, the social effects could be disastrous. What is needed, then, is the establishment of a system of general education, which will itself facilitate a process of guided social change, and create an environment in which improvements in crop husbandry can be introduced.

The degree to which a government promotes, and the farming community adopts pest control measures is often closely linked with the stage of economic growth and development of a particular nation. In West Africa, the maize crop is usually grown by small farmers. It is dried in the sun and stored not in silos but in sacks, to which small quantities of insecticide have to be added. The commercially-produced pesticide is sold to the peasant with a sealable polythene bag at a price within the range of his budget. However, since the government does not recognize the urgency of the need, or cannot find the time and money to organise the supply of the chemical, none is available when required. Moreover, the farmers are not actually told how the pesticide works, and may not seal the bags properly, rendering the whole operation useless (Brenner, 1971).

In contrast, the economy in Ghana has reached a higher level. At 74%, agricultural exports as a proportion of total exports in 1970 were at a relatively low level compared with those of other, less developed African states (F.A.O., 1970a). Pesticides were used widely when Ghanaian cocoa trees were attacked by capsid and the "swollen shoot" virus disease. As the cash crop was handled through export habours, the government were able to levy taxes and use part of the proceeds to buy pesticides. These were distributed to farmers experienced in commercial agriculture, who were then able to make good use of them. Such governmental intervention is unlikely to occur unless the economy has reached a relatively high stage of development (Brenner, 1971).

An ambitious attempt to influence Government, on a world-wide scale, was made in 1970 by the Food and Agriculture Organisation of the United Nations by the publication of the Indicative World Plan for Agricultural Development (F.A.O., 1970b). The plan strongly recommends the increased use of crop protection measures, as well as the use of more fertilizer, mechanisation and better irrigation. However, it warns that: "As the constraints imposed by poor water control, low soil fertility and lack of responsive varieties are removed, pests, diseases and weeds may well represent the main obstacle to the continued expansion of food production in much of Asia, the Near East, North Africa and Coastal Western Latin America". These regions include most of the "developing" countries, which were so designated by the F.A.O. in 1952, as distinct from "developed" countries such as those in Western Europe and the U.S.A. whose inhabitants enjoy a markedly higher standard of living.

The very intensification of agriculture urged by the F.A.O. as a means of raising productivity in developing countries inevitably alters the environment, often to create more favourable conditions for pests. This increases the risk to the grower, and the use of crop protection methods is therefore recommended as an insurance measure. The speed and range of modern transportation renders natural barriers unreliable as a defence against the movement of pests and disease organisms. Thus, Cammack (1958) suggests that air transport was responsible for the introduction of maize rust (<u>Puccinia polysora</u>) to Africa. In Central and South America, where it originated, the disease was never found to inflict severe losses, but on its appearance in Sierra Leone in 1949 its virulence caused alarm. The speed with which the rust devastated maize crops as it swept across the continent and beyond typifies what a relatively insignificant disease can do in a new and favourable environment.

Also, most of the developing countries, over part at least, of their total area, suffer the disadvantages of a tropical climate, which favours the fast, luxuriant growth not only of crop plants but also of competing weeds, as well as the fungi, insects and other organisms which can so adversely affect the crops, and since there is no cold winter season these may thrive all the year round. In the warm monsoon climate of Bangladesh, for example, the continued presence of fresh green vegetation results in a considerable number of insect and disease problems on almost all the crops grown there (Alam, 1975).

Knapsack sprayers have been used by smallholders in a few tropical countries such as Nigeria, where sprays were used to control black pod of cocoa (Phytophthora palmivora) (Duckham and Masefield, 1971). A major disadvantage, especially in very dry areas, is the large amount of water such sprayers need: they are also too heavy to be used by women and children. Ultra Low Volume (U.L.V.) sprayers which use oils instead of water, do not suffer from either of these faults, and several years ago a massive scheme was organized in Tanzania whereby 150,000 peasant farmers, growing 117,000 ha of cotton, were supplied with U.L.V. spraying devices ("Ulvas") and an insecticide, endosulfan. Demonstrators explained to the farmers that the Ulvas produced a mist or smoke, and the idea was to "smoke the insects out". There were technical problems in that locally-made parts proved unreliable and there was some doubt as to whether the insecticide was too toxic for use by peasants. The farmers themselves approved the simplicity and cheapness of the apparatus, and the ease with which the season's requirements of insecticide could be calculated (Wrigley, 1975).

Rice is the staple food of many tropical peoples. In India, one to three crops are grown each year, on 38 million ha, supplying 40% of India's food grain requirements. After a long programme of breeding experiments, the first high-yielding dwarf variety was introduced in 1967. Progressive farmers all over India responded to the challenge of the new "miracle" strains and so began a transition from the traditional subsistence farming to commercial agriculture (Roy and Thapar, 1972). In return for investments in fertilizer and spray chemicals they produced yields that were several times higher than with the older varieties. The farmers were supported by the country's first-ever guaranteed price support scheme for food grain.

Conversely, farmers in the traditional rice-growing areas have been slow to adopt the new varieties. Ram (1975) lists several reasons for this, one of which is the fact that most of the rice in these areas is grown in the hot, humid, rainy season, so that the crop is exposed to vagaries of several types of harmful pests and diseases. Ram mentions other major obstacles to their adoption as being weak communication links between research and extension agencies and farmers in their local languages, and poor transport due to bad road and rail links between villages and the main cities. Also, the farms are scattered and very tiny. Irrigation is poorly controlled and farmers are not accustomed to using chemical methods of crop protection or fertilization. In addition, credit and marketing facilities are grossly inadequate, and this fact alone would render the adoption of more up-to-date methods almost impossible.

International co-operation and the sharing of experience and expertise in the development of effective defence and control systems are eminently desirable. To this end, the F.A.O. has assisted several of its member governments in the formation of regional plant protection organisations, to act as co-ordinating and advisory bodies. Without international co-operation, the massive strides towards solution of the locust problem would not have been possible. Locusts are cosmopolitan insects; swarms bred in one country can spread over many neighbouring territories. Generally, locusts live and breed in countries with subsistence agriculture, so that the crop damage they inflict strikes directly at the peasant farmer, and forces the governments concerned to spend valuable foreign exchange currency on importing replacement food supplies.

Haskell (1973) cites the decline of the Red Locust (Nomadacris septemfasciata) on Mauritius, due to the increase in sugar monoculture, as encouraging evidence that the threat from locusts will decrease during the next 15-20 years. Unfortunately however, the Sudan, Senegal, Saudi Arabia and Thailand have all suffered an increase in grasshopper problems correlated with a similar spread of agriculture. Haskell stresses the need for an ecological basis to insect pest control, which would produce "better and safer control techniques and.........allow the amassing of a body of ecological data that could be used to predict some of the ecological consequences of agricultural development".

The need for an ecological approach has also been stressed by Rahman (1975) who, although admitting that the use of herbicides for weed control in tea plantations in the Middle East has increased yields and reduced expenditure, points out that new problem weeds are beginning to appear, creating a need for more specific herbicides.

Whilst they have been used extensively on large plantations, herbicides have, so far, been little used by peasant farmers, although losses from weeds in tropical cropping can be large (for example, a one-third reduction in maize yields in Kenya and up to a 50% reduction in coffee yield in Uganda have been noted due to weeds). Weed control using mainly hoes and cutlasses probably demands more time and energy than any other aspect of crop production, and it is very likely that this is the factor which has limited the size of tropical peasant farms. A useful technical advance might be an improvement in the hand implements which small farmers use in weed control (Moody and Ezumah, 1974).

Some workers continue to stress the desirability of making herbicides which would suit the requirements of the peasant farmer. Such a herbicide must possess sufficiently low mammalian toxicity to permit its presence in the cooking pot, and should be tolerated by all the crops grown on small tropical holdings. Ogborn suggested that herbicides could be very useful in countries such as Nigeria for controlling perennial weeds, and protecting cereal crops from Striga lutea (Ogborn, 1969a). Eventually they might be used for bush clearing, but there might then be a danger that this could perpetuate the shifting agriculture system, whilst the expanding population in most developing countries requires that priority should be given to developing permanent, long-term, arable systems of agriculture.

Perhaps the most important use of herbicides might lie in reducing the seasonal peak in labour demand. Nigerian farmers have been advised repeatedly that they should sow their cotton in June, two months earlier than is customary, and to protect their crop with an insecticidal spray in order to obtain higher yields, but the labour demand imposed by the need to hand-weed and thin their cereal and other food crops planted in May has led them to disregard the advice, to the detriment of the cotton yield (Ogborn, 1969b).

These few examples of the use, and non-use, of crop protection methods suffice to show the dichotomy which exists in developing countries between peasant farming habits and modern commercial agriculture. Attempts are being made to encourage small farmers to adopt pest control measures as an insurance against crop losses, but progress is slow. Meanwhile, every second, throughout the world, births exceed deaths by more than two, and food supplies are not keeping pace with the growth in population (Carefoot and Sprott, 1967). A major difficulty is that of communication; both physical, due to the nature of the terrain, and cultural, due to the persistence of tribal customs and taboos. The problem is an urgent one. Governments in both the developing and the developed countries must co-operate to ensure that the peasant is made aware of the means of increasing his crop yields (and of limiting the size of his family), and more than this, given financial incentives to use such means, since, in the words of Maurice Zinkin (1971), "Virtually all economic activity is accompanied by risk. If a producer is a subsistence farmer, he runs the most serious risk of all; should his crops fail, he may starve".

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THE PROBLEM OF AVENA FATUA AND ITS CONTROL IN POLAND

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Summary The paper presents results of investigations on the occurrence of Avena fatua in Poland, its harmfulness to spring wheat, spring barley and sugar beet and its chemical control in these crops. The best control of this species of weed was obtained by using the following herbicides: benzoylprop-ethyl, flamprop-methyl, difenzoquat in wheat, flamprop-isopropyl in barley and diclofop-methyl in mixture with phenmedipham in sugar beet.

INTRODUCTION

Avena fatua occurs in Poland on light as well as heavy soils. Its development is, however, more intensive on soils most favourable to wheat and rye and those fairly favourable to wheat. This weed infests mainly spring cereals, sugar beet, potatoes, flax and legumes and to a lesser extent rape and maize. Economically it is a particular problem in spring wheat, spring barley and sugar beet. Weed infestation of sugar beet by Avena fatua often necessitates the ploughing in of the crop as hand weeding is not economic. The most effective method of controlling this weed is by using herbicides.

In Poland, barban is the most widely used herbicide for the control of Avena fatua in wheat and barley. Tri-allate is used to a lesser extent in cereals. Tri-allate and barban in mixture with phenmedipham are used in sugar beet (Rola, H. 1972).

METHOD AND MATERIALS

Observations on the occurrence of Avena fatua were carried out in 1971-1975 with the use of the modified Braun-Blanquet method (Rola, Kuzniewski, 1974). Investigations covering the state and degree of crop contamination were carried out on cultivated areas twice in each growing season at designated points throughout the whole country.

Investigations on the effect of the degree of weed infestation in spring wheat crops were carried out in controlled conditions on 1 m^2 micro plots with a constant amount of cereal per unit area and differing densities of Avena fatua. Apart from these tests, the above mentioned studies were performed using a simpler method on field scale production areas with different degrees of weed infestation. The amount of Avena fatua and crop in a unit area per plot was calculated.

Studies on the selection of herbicides for Avena fatua control in cereals and sugar beet were carried out in 1975-76 in small plot trials and field scale trials. Field trials were performed on natural populations of Avena fatua in the provinces of Wroclaw, Opole and Gdansk. In the small plot trials the following herbicides were evaluated:

difenzoquat 20% a.i.
chlorfenprop-methyl 80% a.i.
phenmedipham 16.5 % a.i.
barban 12.5% a.i.
metamitron 70% a.i.
diclofop-methyl 36% a.i.
flamprop-methyl 15% a.i.
flamprop-isopropyl 20% a.i. (WL 29762)
ethofumesate 20% a.i.
benzoylprop-ethyl 20% a.i.
ipuron + dinoterb (Exp 3143)
flamprop-isopropyl 20% a.i. (WL 43425)
barban + mecoprop + MCPB + dichlorprop (Cr 13781)
carbodimedon 75% a.i.

RESULTS

Occurrence of *Avena fatua* in Poland

The range and occurrence of *Avena fatua* in Poland is enlarging and increasing each year. An enquiry in 1964 showed a high incidence of this species in the western provinces, i.e. Wroclaw, Opole, Zielona Góra, in the North - in the Gdansk province and in the Lublin province in the eastern part of Poland (Pejka, 1971). Investigations on the regional distribution of *Avena fatua* carried out in 1971-75 showed that it now occurs throughout the whole country, with dense populations in the provinces of Gdansk, Opole, Zielona Góra, Wroclaw and Lublin (Fig. 1). In the provinces of Gdansk, Lublin and Opole about 30% of the spring cereals crops and 15-20% of sugar beet crops are infested with *Avena fatua*. However, this mainly concerns individual farms where there has been many years of agricultural neglect and now also the use of combined harvesting has contributed to the spreading of this weed.

Table 1

Occurrence of *Avena fatua* in spring cereals and sugar beet in Poland (1971-1975)

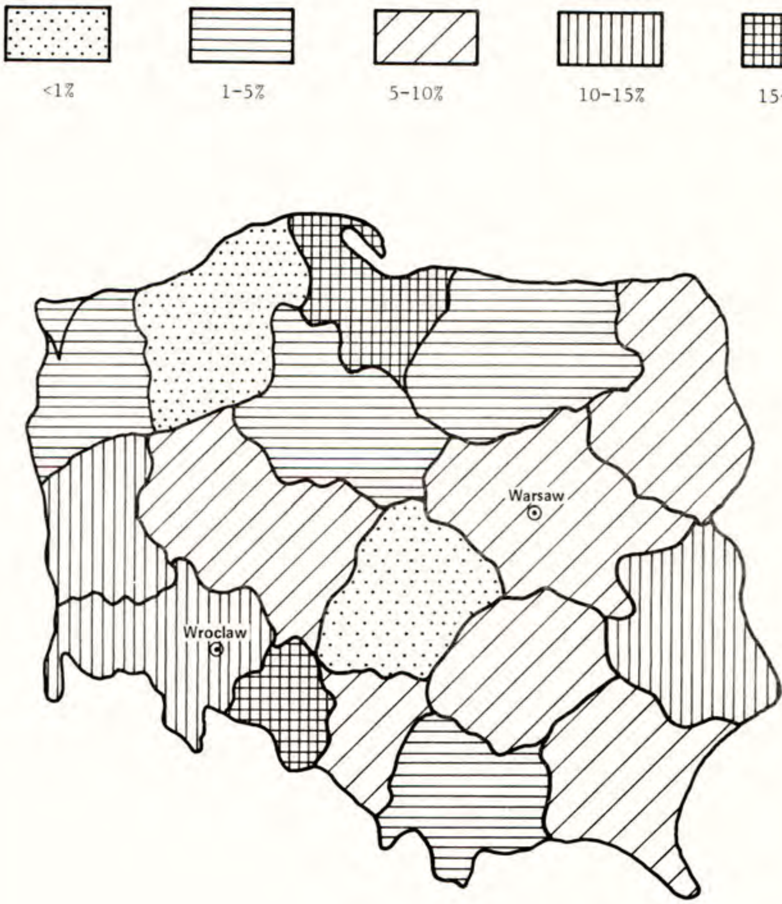
Province	Spring cereals		Sugar beet	
	A	B	A	B
Bialystok	301	16.2	111	4.5
Bydgoszcz	37	2.7	154	5.1
Gdansk	759	27.0	259	21.2
Katowice	491	7.7	250	0.8
Koszalin	347	-	74	1.3
Kielce	425	19.2	129	7.7
Krakow	294	7.4	136	5.1
Lublin	417	29.9	217	2.3
Lodz	102	0.9	108	
Olsztyn	434	9.2	210	0.4
Opole	721	33.1	318	13.8
Poznan	475	21.2	389	7.9
Rzeszow	666	15.3	314	3.5
Szezecin	329	4.5	322	3.7
Warszawa	958	14.2	408	3.6
Wroclaw	1207	17.6	581	7.4
Zielona Góra	502	20.1	213	9.8

A - number of fields observed B - % of fields infested with *Avena fatua*

Figure 1

The distribution of *Avena fatua* in Poland (1971-1975)

in relation to the number of observed fields



Effect of Avena fatua on spring wheat crops

In Poland's climatic conditions the growth of Avena fatua takes place mainly in the spring. Thus its competitive action is in spring cereals, especially wheat and barley. The higher the intensity of the weed in a unit area, the lower the crop yield - this is confirmed by results shown in Table 2.

Table 2

Effect of degree of infestation with Avena fatua on spring wheat crops (Wroclaw 1972-73)

Avena fatua panicles/m^2	% in relation to control "0"			
	Number of wheat ears/m^2	Number of wheat grains/ear	Weight of wheat grain/m^2	Weight of 100 wheat grains
0	100	100	100	100
5-25	83	97	83	98
26-50	81	96	79	98
51-100	75	90	63	99
101-150	85	89	60	92

Control of Avena fatua by cultivation

Long-standing reaearch shows that cultivation is not effectively controlling this persistent weed. The recommended methods of controlling wild-oats by post-harvest cultivation are only relatively effective in years favouring the growth of Avena fatua, i.e. those with moist and warm weather. Early first ploughing in the autumn stimulates germination of Avena fatua seeds, stored in the soil during previous years. Mass growth of wild-oats may then be destroyed by frequent harrowing or field cultivating. Although such steps reduce the intensity of infestations they do not prevent growth of wild-oats in spring, from the middle of March until the end of April. For this reason no greater practical results may be achieved by recommending the delayed sowing of grain in order to enable the mechanical destruction of seedlings of Avena fatua in the pre-sowing tillage.

Chemical control in spring cereals

Herbicides studied in the course of the trials on wheat controlled Avena fatua to various degrees (Table 3). The best results were obtained in plots treated with benzoylprop-ethyl and flamprop-methyl. In general none of the herbicides gave any visible phytotoxic effect on the crop.

The treatment with difenzoquat was an exception, causing transient changes in leaf colour of the wheat and a slight retardation of its growth without any apparent serious effect on crop development. All plots treated with herbicides yielded wheat crops showing a 15-22% increase in yield compared with untreated control.

In the 1975 spring barley trials (Table 4) the best control of Avena fatua was obtained with chlorfenprop-methyl and flamprop-isopropyl (WL 29762). The experimental mixture 3143 caused damage to the barley and a decrease in crop yield.

Table 3

The control of Avena fatua in spring wheat with herbicides

(variety Carola). (Wroclaw 1975-76)

Treatment	Dose kg a.i/ha	Timing of application	Evaluation by EWRC scale 1-9		Degree of soil coverage as % before harvest		Yield of crop	
			Wheat	A. fatua	Wheat	A. fatua	t/ha	%
Control			1	9	94	75	2.20	100
Difenzoquat	1	I	2-3	4	88	14	2.55	115.9
Chlorfenprop-methyl	4	I	1	5-6	96	35	2.47	112.3
Flamprop-methyl	0.45	I	1	3-4	95	13	2.69	122.3
Benzoylprop-ethyl	1.5	I	1	2-3	96	7	2.67	121.4
Flamprop-methyl	0.45	II	1	1	94	4	2.56	117.0
Benzoylprop-ethyl	1.5	II	1	1	92	2	2.50	113.6

Crop stage at application:- I - 4-5 leaf stage of Avena fatua
II - early shooting stage of Avena fatua

Table 4

The control of Avena fatua in spring barley with herbicides. (Wroclaw 1975)

Treatment	Dose kg a.i/ha	Degree of soil coverage in % before harvest		Crop yield	
		Barley	A. fatua	t/ha	%
Control		98	43	2.65	100
Barban + CMPP + MCPB + 2,4-DP(CR 13781)	3.5	99	20	2.38	89.8
Chlorfenprop-methyl	4.0	99	13	2.86	107.9
Ipuron + dinoterb (Exp 3143)	3.0	86	25	1.99	75.1
Flamprop-isopropyl (WL 29762)	1.2	96	18	2.63	99.2

Timing of application:- 4-5 leaf stage of Avena fatua

In the 1976 spring barley trials (Table 5) the best results were obtained with flamprop-isopropyl (WL 29762 and WL 43425) sprayed at the 4-5 leaf and shooting stage of the wild oat and the mixture CR 13781 at the 4-5 leaf stage of the weed.

Some of the herbicides were also tested in field-scale production trials. In all cases positive results were obtained (Table 6).

Table 5

Control of *Avena fatua* in spring barley. (Polanowice 1976)

Treatment	Dose kg a.i./ha	Timing of application	Evaluation using EWRC scale 1-9 (20.6.76)		Degree of soil coverage as % (harvested 15.8.76)	
			Barley	*A. fatua*	Barley	*A. fatua*
Control			1	9	100	85
CR 13781	3.5	I	1	3-4	100	16
Chlorfenprop-methyl	4.0	I	1	7	100	63
Flamprop-isopropyl (WL 29762)	1.2	I	1	3-4	100	25
Flamprop-isopropyl (WL 43425)	0.6	I	1	3	100	16
Flamprop-isopropyl (WL 29762)	1.2	II	1	2	100	12
Flamprop-isopropyl (WL 43425)	0.6	II	1	2	100	4

Timing of application:- I - 4-5 leaf stage of *Avena fatua*
II - shooting and first node stage of *Avena fatua*

Table 6

Evaluation of the efficiency of herbicides for the control of *Avena fatua* in spring wheat and spring barley in field conditions

Treatment	Year	No. of trials	Degree of *A. fatua* occurrence as %		Crop yield t/ha		% Yield increase compare with control
			Control	Treatment	Control	Treatment	
			Spring wheat				
Benzoylprop-ethyl 1.5 kg a.i./ha	1972	2	48	12	1.73	2.26	31
	1973	5	75	1	2.13	2.78	31
	1974	2	70	5	2.42	3.35	38
	1975	6	68	0	2.02	2.80	39
	1976	1	95	0	2.48	3.56	40
Flamprop-methyl 0.45 kg a.i./ha	1975	2	75	1	2.15	2.32	8
	1976	3	56	0	2.58	3.44	33
Chlorfenprop-methyl 4 kg a.i./ha	1976	1	75	25	1.89	2.70	42
			Spring barley				
Flamprop-isopropyl (WL 29762) 2 kg a.i./ha	1975	2	45	12	1.98	2.65	34
	1976	2	78	18	2.94	4.18	42

Sugar beet

The comparison of all herbicides used in the tests showed that the best results were obtained by a mixture of diclofop-methyl + phenmedipham applied at the 4-5 leaf stage of Avena fatua.

Table 7

The control of Avena fatua in sugar beet with herbicides

(Wroclaw 1976 - Szukalice)

Treatment	Dose kg a.i./ha	Timing of application by leaf stage of A. fatua	Evaluation using EWRC scale 1-9 (4.6.76)	
			Sugar beet	A. fatua
1. Control			1	9
2. carbodimedon	0.75	1-2	1	7-8
3. carbodimedon + phenmedipham	0.75 + 1	1-2	1	8
4. barban + phenmedipham	0.75 + 1	1-2	1	5-6
5. ethofumesate + phenmedipham	1 + 1	1-2	1	7-8
6. metamitron + chlorfenprop	3.5 + 4	1-2	1	7
7. diclofop-methyl	1.5	3-4	1	3
8. diclofop-methyl + phenmedipham	1.2 + 0.8	3-4	1	1

DISCUSSION

In Poland Avena fatua is a problem in spring cereals, sugar beet and occasionally in flax. In other crops, cultivations and the competitive effect of the crop plants limits the development of this weed. Field trials on the chemical control of wild-oats were carried out mainly in spring wheat, spring barley and sugar beet.

In recent years the best results for the control of Avena fatua in spring wheat were obtained with flamprop-methyl and benzoylprop-ethyl. With regard to the competitive action of wild oats on spring wheat, both herbicides should be applied at the early stage of growth, i.e. at the 4-5 leaf stage of Avena fatua. Similar results were obtained for difenzoquat though this herbicide still needs further testing since different varieties of wheat show different reactions to this compound. Also the results for chlorfenprop-methyl were not consistent. This may be due to the different stages of wild-oat development at the time of spraying.

In spring barley, both herbicides tested, i.e. flamprop-isopropyl and the mixture containing barban, CMPP, MCPB and 2,4-DP (CR 13781) are interesting but they still need testing further in large scale field production trials.

The mixture containing ipuron + dinoterb (Exp 3143) was found to be too phytotoxic to be used for the treatment of spring cereals.

The results of the field tests showed that those herbicides giving good control of wild-oat in spring wheat and spring barley give good yield gains if the amount of Avena fatua panicles exceeds 25 m^2. In such cases, chemical treatment is economically attractive.

In sugar beet diclofop-methyl is of special importance. This herbicide, in mixture with phenmedipham, kills Avena fatua very quickly and completely without any negative effect on the crop. The other herbicides tested (see Table 7) are much weaker, i.e. they inhibit the growth of Avena fatua but do not destroy it entirely. Crops treated with these herbicides needed additional cultivations to give adequate weed control.

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THE USE OF HERBICIDES BY LOCAL AUTHORITIES

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Summary A discussion paper on the management and practical factors that influence the use of herbicides by Local Authorities.

INTRODUCTION

Local Authorities as a whole are probably the largest single users of herbicides for vegetation control in Amenity & Industrial areas and this paper attempts to explore some of the factors that influence their use of herbicides, both now and in the future. The first difficulty in this task is that, although Local Authorities as a whole are large users of herbicides, they vary considerably in their size, responsibilities and political and/or management policies, and they also work in many different social and geographical environments. I must therefore make it clear that this paper is largely based on my experience of working with a large "Shire" County in the South-East of England and my associated involvement is advising District and Parish Councils on herbicide uses.

WHY DO LOCAL AUTHORITIES USE HERBICIDES?

In many situations it is possible to make cost savings by using herbicides and although this is obviously of prime importance, it is not always the dominant factor that leads a Local Authority to use chemicals instead of manual or mechanical means.

Firstly there are tasks for which it is impractical to use any other method. For example the selective weed control in sports turf and lawns and the control of vegetation of motorway central reservations where there are obvious dangers in routine mowing between opposing fast lanes of traffic. As time goes on more jobs are coming into this category, e.g. weed control on pavements and kerbs, as it becomes more widely known that labour saving methods are available and in the light of this knowledge, fewer people are prepared to undertake the drudgery of the former methods.

A second major factor that has encouraged the use of herbicides in recent years has been a serious shortage of suitable labour that has made it essential, for instance, to use growth retardents, just to keep the situation under control through the main growing season. The result of this has been that some Authorities have started to use new techniques which they might not have done in other circumstances and the experience they have gained has enabled them to improve the techniques and subsequently make significant cost savings without reducing their maintenance standards.

CONSTRAINTS ON HERBICIDE USE

Despite the apparent cost savings and the other advantages that I have mentioned the development of herbicide use by Local Authorities does not appear to have been as rapid as in agriculture and commercial horticulture.

In attempting to determine why this has been the case it is important to understand that the management aim in a Local Authority is usually more complex than the need to reduce costs and thereby increase output and/or profits. In practice there could be strong political opposition to methods of work that would conflict with local policies to reduce unemployment and also the working methods must generally be acceptable to the public at large. In addition labour saving techniques are usually only worth adopting if there is a need to raise standards or if the staff can be reduced or transferred to other productive work. In the absence of vacancies, staff reductions can usually only be made as opportunities arise through natural wastage as very few, if any, Local Authorities would want to adopt redundancies if they had any choice. As a result the introduction of labour saving herbicides could bring about a short term increase in costs, particularly if there is a rapid change over on a large scale. This problem is not usually met in agriculture or commercial horticulture where any saving in labour can usually be diverted towards increased production.

Another powerful factor that acts against the use of herbicides is the environmental or conservation attitudes of large sections of the public, Local Authority members and their staff. In many cases there are quite justifiable objections to needlessly destroying plants and wild-life in the interests of tidyness. Herbicides enable this to be done much more cheaply and efficiently than has previously been the case and there is therefore a strong groundswell of opinion against their indiscriminate use. There is also the opinion that once a man has a gun in his hand it is difficult to control what he shoots, and therefore herbicides should only be made available under the strictest control for carefully defined objectives.

The need for careful use of herbicides is fully justified but there are many people, often with considerable influence, who have an unshakeable belief against the of _any_ chemicals in the natural environment. While it must be accepted that there are still gaps in mankind's knowledge on the long-term effects of the chemicals that we use, the extremists in the environmental lobby are not usually satisfied by the thorough testing and screening of herbicides by manufacturers and Government agencies. As a result even the use of the most innocuous of chemicals can result in strong complaints from neighbouring gardeners who fear residues on their vegetables, and school teachers or parents who fear disastrous effects on their children. The staff who apply the chemicals, and may be in contact with them for long periods, are obviously also concerned about the safety of the materials and their unease is often increased if the chemicals require the wearing of special protective clothing. Also the public at large will suspect the worst if they see heavily protected operators. Because of these pressures, Local Authorities' managers are often loath to attempt to introduce new uses of herbicides unless there are clear economic or other advantages. Even then they will probably prefer to introduce herbicides gradually, testing public reaction and gaining experience as they go.

PRACTICAL PROBLEMS IN USING HERBICIDES

To the uninitiated there is a confusing range of herbicides for his use and ideally the choice of material and formulation should be left to an experienced specialist. Only the larger Local Authorities can usually justify the employment of such a specialist and so many smaller Authorities, and other organisations, have to rely almost entirely on the advice they receive from the manufacturers' representatives. Even with this it can still be difficult and time-consuming to evaluate the "best buy" and there is a need for an independant organisation that could advise Local Authorities. The Weed Research Organisation makes a valuable contribution to the need for unbiased information through the publication of the Weed Control Handbook but this cannot be a complete substitute for an experienced advis r.

Even if the Local Authority manager has the necessary technical knowledge on herbicides there is often a considerable "knowledge gap" between him and the people who actually apply them and there is thus a clear possibility of the materials being mis-used both to the danger of the operators and the public and to the detriment of desirable plant species. Because of the geographical distribution of the work, it is often difficult to overcome this "knowledge gap" by close supervision, as, for instance, on a single farm or holding. In practice, in a single Authority it is quite likely that up to hundreds of men may all be using herbicides on sites spread over many square miles and just one significant accident or incident may jeopardise the whole policy because of adverse public reaction. For many reasons it is therefore essential that all the staff are properly trained before herbicides are issued for general use.

This training is not as easy as it may first appear because, in the case of experienced staff, it might first be necessary to change the belief of a lifetime and, for instance, persuade a man that roses will grow without frequent hoeing and with Simazine round their roots. Coupled with this the labour-saving properties of the herbicides can appear to threaten the gardener's livelihood and, at best, it may take several seasons to convince him that the herbicide technique really works. Even then he may still believe the old method is better. One further difficulty is that the operative must be able to calculate dilution rates and calibrate sprayers if he is going to use a range of different materials. As even simple mathematics are not usually part of a gardener's or groundsman's work the calculations that are required can often be another reason for rejecting herbicides in favour of traditional methods. To ease this training problem, herbicides should be simple to use and in particular those with critical dosage rates should be avoided because of the disasters than can result from adding "one for luck" when mixing up or giving an extra application "just to make sure".

One way of overcoming the training problem is either to employ contractors or use special gangs for herbicide application. This has many advantages and as a general rule is the most efficient way. However, in many open spaces and gardens the quality of the maintenance relies heavily on the interest and motivation of the individual groundsman or gardener who does not usually wish to be confined to the boredom of the production line by only carrying out the simple routine tasks. I have therefore taken the view that, wherever possible, the person who normally cares for a site should also apply any herbicides that are used, even if it involves using knapsack sprayers instead of larger capacity sprayers. This would not apply to the large scale application of selectives in playing fields but it would apply to all the fence line and border spraying and selective spraying on small areas where the care of application can have a significant effect on the subsequent appearance of the site. Fortunately most of this spraying can be done outside the main growing season so that the extra labour requirement does not usually involve any significant additional costs.

PACKAGING & LABELLING

In the interests of economy many purchasing officers will naturally go for the apparent "good buy" of large bulk packs. Unfortunately these are really only suitable for use either by contractors or for large scale spraying. These bulk packs are not usually convenient for smaller scale use and either excessive amounts have to be issued to individual groundsmen or there is a temptation to transfer the chemical to old cans, paper bags or even milk bottles which have no relevant instructions on them, safety or otherwise.

Bulk containers can therefore be a false economy and smaller packs bulked together for ease of transport are usually more convenient.

In some circumstances there could be advantages in buying very small single dose packs similar to those produced for the domestic market. Unfortunately these are usually too small for most professional users as they can only cover as little as 100 sq. ft. However, 100 sq. yard packs, enough for a 2 gallon knapsack sprayer would be worth considering provided, of course, that the extra packaging cost can be kept within reason.

Whatever the pack size it is essential that all the packages are clearly labelled in accordance with the recommendations made by the Ministry of Agriculture Fisheries & Food. This appears to be done by all the main manufacturers but there is too often a tendancy to put the brand name in large print while the name of the active ingredient is almost hidden away in the small print. The emphasis on brand names is no doubt for good commercial reasons but it does make it difficult for the user to know immediately what he is dealing with and in some cases similar brand names cover very different sorts of materials. Obviously long chemical names can be confusing as well but I do feel that the active ingredient of any formulation should be more prominently displayed on packages and sales literature.

SPRAYS OR GRANULES

Although granular preparations are more expensive to buy, the extra cost can be recouped in easier applications and the problems of spray drift are largely avoided. However, they are more difficult to apply accurately and I have yet to see a satisfactory application method for confined spaces. As a result it is my experience that over-dosing is much more common with granules. For these reasons I have generally relied on granules as a standby for very small areas that would not justify making up a tankful of spray and have used sprays for the majority of the work.

The comparatively new developments in Ultra Low Volume Spraying may provide a further alternative to normal spraying or granules but the small drop sizes required for U.L.V. spraying would appear to increase the risk of drift damage in confined spaces.

THE FUTURE USE OF HERBICIDES BY LOCAL AUTHORITIES

In the immediate future the sales of herbicides to Local Authorities are likely to be reduced by the budget cuts on public expenditure as the use of herbicides is an area in which short-term cuts can be made without serious effects on the service, or redundancy.

In contradiction to this there will be an even greater need to use labour-saving techniques but these will often have to take second priority in the immediate future where Authorities are trying to cope with over-manning situations and avoid redundancies brought about by budget cuts.

In the longer term we can expect the labour and cost saving advantages of herbicides to have greater influence and for them to become more acceptable to staff and public alike as staff and managers gain more experience of their use and the traditional hand methods fade into the past. In this climate of opinion it should be easier for managers to adopt new herbicides and techniques as they are developed. At present it would seem that the range of materials that is available will deal with the majority of our weed problems provided they are used with proper technical knowledge. We can hope that further development and refinement will make the materials more effective and convenient to use. Nevertheless, there may well be further radical developments that will provide herbicides that have uses beyond those that we envisage at present. For instance, growth controllers that will encourage lateral at the expense of vertical growth in grass might become a real alternative to mowing amenity lawns and even sports turf.

The other long-term development that I feel will affect the use of herbicides is the changing conception of what constitutes a weed. Only a few years ago selective weed control was practiced on many roadside verges but now it is generally accepted that as many different plants as possible should be allowed to grow there. The same change in attitudes is being reflected in amenity lawns with pure grass swards being more and more reserved for sports surfaces. Throughout the country Landscape Managers are experimenting and developing techniques to provide a more natural appearance, particularly in public open spaces where grass in being left longer and shrubs or ground cover are replacing summer bedding. While these trends may reduce the need for the herbicides that we have used in the past, they may well create the need for new and more sophisticated products in the future which will be more specific in what they control.

Acknowledgements

I am indebted to the Kent County Council for giving me the opportunity of presenting this paper and I would like to make it clear that the views I have expressed are my own and do not necessarily reflect the policies and views of my employer.

SPRAY TIMING AND THE IDENTIFICATION OF CEREAL GROWTH STAGES

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Summary Farmers have to judge the stages of growth at which a cereal crop is most tolerant of herbicides by the external appearance of the plants. To describe the appropriate stages, herbicide recommendations should adopt the terminology of the decimal code recently proposed by Zadoks, Chang and Konzak (1974).

Tolerance of cereals to the growth regulator herbicides depends on the development of the young ears at the stem apices. Emphasis ought, therefore, to be placed on the external characters that best reflect apical development, during the stages up to heading. Recent studies at the Weed Research Organization indicate that a measure of the leaf sheath lengths may provide a better guide to apical development than the confusing term 'fully-tillered stage', currently used in winter wheat herbicide recommendations.

Minor modifications to Zadoks' growth stage code are suggested to improve its prediction of apical development and, hence, its value to the herbicide user.

Résumé: Les fermiers doivent juger d'après la mine des plantes les stades auxquels une culture céréalière supporte le mieux un traitement herbicide. Pour décrire les stades convenables il faudrait utiliser dans les avis d'emploi d'herbicides la terminologie du code décimal proposé recemment par Zadoks, Chang et Konzak (1974).

La tolérance des céréales à l'égard des herbicides régulateurs de croissance est fonction du développement des jeunes épis au bout des tiges. Il faudrait alors souligner les aspects extérieurs de la plante qui indiquent, avec la plus de précision, le développement apical pendant les stades qui précèdent l'epiaison. Des études récentes à la Weed Research Organization suggèrent qu'un mesurage de la longueur de la gaine foliaire peut fournir une meilleure indication du développement apical que la phrase imprécise "stade plein tallage" qui figure actuellement dans les avis d'emploi des herbicides pour froment d'hiver.

On propose de légères modifications au code Zadok pour rendre plus sûre l'indication qu'il donne due développement apical et ainsi rehausser sa valeur au fermier qui se sert d'herbicides.

INTRODUCTION

The variation in the tolerance of herbicides by cereal crops at different stages of growth has long been appreciated (Templeman, 1946; Large and Dillon Weston, 1951). However, a study of the literature (ARC Weed Research Organization, 1975) reveals varied and inadequate descriptions of cereal growth stages. Some authors have been content with a measurement of crop height at the time of spraying, while a few have dissected samples of plants in order to record the appearance of their apical meristems. This makes comparison between research reports difficult and seriously reduces the value of the extensive literature on the tolerance of herbicides by cereals.

A universally acceptable code, describing cereal growth from germination to harvest, is required. Several codes have been proposed, modified and used on a limited scale. It is to be hoped that the most recent proposition, that of Zadoks, Chang and Konzak (1974), will achieve international use. However, all growth stage keys attempt to break the continuous progression of plant development into a series of discrete steps and the way in which this is done tends to reflect the particular interest of the key's designer. The special requirements of the herbicide user are mainly related to identifying the most tolerant stages of cereal growth.

The tolerance of growth regulator herbicides is determined by the stage of development reached by the apical meristems (Andersen and Hermansen, 1950; Friesen and Olson, 1953; Myers, 1953). For example, some herbicides, such as 2,4-D and MCPA, can cause ear deformities if sprayed before the spikelets of the young ears have been determined (Large and Dillon Weston, 1961; Fryer and Elliott, 1953). Sprayed at a later stage, when the cells are dividing to form the pollen and ovules, they sometimes lead to sterility. The upper spikelets fail to produce grain and give the ear a characteristic 'rat-tailed' appearance (Longchamp et al, 1952; Pinthus and Natowitz, 1967). Other herbicides, the benzoic acid derivatives in particular, can cause an equally drastic depression in yield when sprayed during jointing, while the anther and carpel primordia are developing (Holroyd, 1962; Friesen et al, 1964; Munro, 1972). Narrow ears, in which the grains are shrivelled,are produced and frequently invaded by secondary black moulds (Cladosporium spp).

The problem of precise growth stage identification extends to other aspects of cereal agronomy. For example, the crop stages most sensitive to weed competition and crop density, those most responsive to nutrient applications and the environmental control of potential yield may all be related to apical development (Evans, 1974; Kirby, 1967; Laloux, 1975; Gallagher et al, 1976).

A method of predicting apical development from external, easily identified, characters of the plant is required and should be incorporated in any satisfactory growth stage key. The intention of this paper is to trace briefly the origin of Zadoks' code from the various growth stage keys in current use and to suggest amendments to the code which might improve its value as a guide to spray timing. The growth stage descriptions presently used in herbicide recommendations (Fryer and Makepeace, 1972) are criticised and an attempt is made to equate them to stages in Zadoks' code. Particular attention is given to recent studies of apical development and the external appearance of winter wheat plants, at the Weed Research Organization.

THE GROWTH STAGE KEYS

The best known key to cereal growth stages is that prepared by Feekes (1941) and later illustrated and improved by Large (1954). Essentially it describes the development of wheat but can be applied to barley, oat and rye crops. The development of the crop is divided into eleven, more or less discrete, stages with sub-divisions at the latter end of the scale, in the heading, flowering and ripening phases.

Another development of Feekes' scale was devised by Keller and Baggiolini (1954). They proposed twenty-two 'reference' stages by which to describe the development of wheat and designated them alphabetically instead of numerically. The key is more explicit than the Feekes - Large scale at the early, pre-tillering, phase but less so during heading and flowering. Otherwise, the keys are very similar and both are well illustrated.

Chancellor (1966) suggested that the Keller - Baggiolini scale might be improved by the addition of leaf and tiller numbers during the stages up to jointing.

The most recent proposal by Zadoks, Chang and Konzak (1974) is again closely related to the Feekes-Large scale but uses a decimal notation to facilitate data processing. Minor modifications are incorporated to allow its application to all cereals. During the earlier stages of growth, it differs from the other scales in describing individual plants rather than classifying crop growth stages. Thus the two digit codes, in which the first digit refers to one of ten principal growth stages and the second to a sub-division, can be used concurrently. For example, a cereal plant might be described as having 6-leaves unfolded (16), a main shoot and 4 tillers (24) and the first node detectable (31).

A set of drawings to illustrate the application of Zadoks' code to winter wheat and spring barley plants is being prepared at the Weed Research Organization in collaboration with cereal physiologists at the Plant Breeding Institute, Cambridge. Examples of winter wheat, during the early stages of growth, are presented in Figure 1.

The herbicide specialist has developed yet another system of growth stage descriptions. This is based on the number of leaves in the main shoot, the appearance of nodes on the stem and the 'fully-tillered stage' in winter cereals (Fryer and Makepeace, 1972). Problems associated with the definition of these terms and equating them to stages on Zadoks' scale are discussed below.

THE DESCRIPTION OF CEREAL GROWTH STAGES IN HERBICIDE RECOMMENDATIONS

Leaf counting

In spring cereals the number of leaves on the main shoots have, so far, proved an adequate guide to spray timing (Myers, 1953; Fryer and Makepeace, 1972). The relationship between leaf number and apical development was studied in spring barley and oats by Andersen (1955). He did not find a precise or invariable relationship but an empirical one that provided a useful guide for the varieties tested under the conditions of his experiments. We should not assume that the criteria developed during the early testing of well established herbicides such as 2,4-D and MCPA (Elliott, 1953) will apply to new varieties and cultivation techniques. Little effort, however, has been expended on up-dating the recommendations derived from this early work.

If leaf number is to be used as a criterion for optimum spray timing, a consistent definition of a main stem leaf is necessary. Only the leaves arising from the main shoot, usually the central and tallest one, should be counted and tillers and their leaves must be excluded. There has been some confusion over the point at which the latest emerging leaf should be counted. Herbicide recommendations have included a leaf only when the tip of the succeeding leaf can be seen (Fryer and Makepeace, 1972). Chancellor (1966) suggested that to count a leaf when at least half the lamina is visible above the sheath of the preceeding leaf, provided a better measure of its contribution to the photosynthetic area of the plant. Kirby and Faris (1970) counted the new leaf when its ligule had emerged and another, earlier, suggestion by Andersen and Hermansen (1950) was to count it only when its length, in centimetres, exceeded a half of its number in the order of appearance. In practice, the differences between records made by the four methods are minor and the simplicity and objectivity of the first recommends it. Although Zadoks' code uses Chancellor's

Fig. 1 Examples of the application of Zadoks' cereal growth stage key to young winter wheat plants.

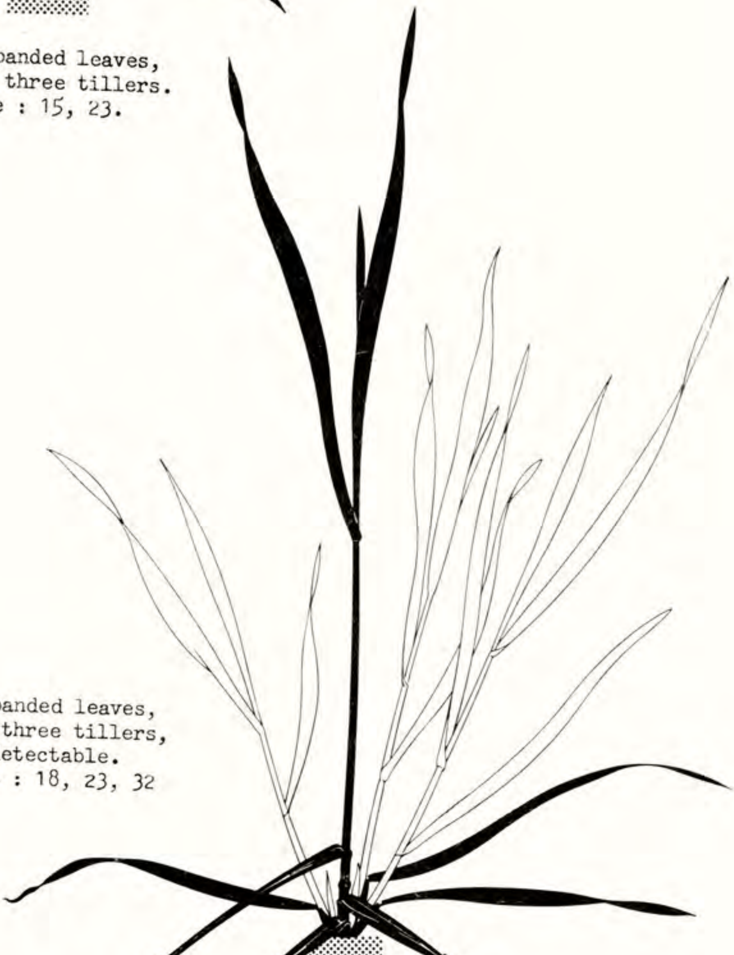
(a) One fully expanded leaf, growth stage : 11

(b) Three fully expanded leaves, main shoot and one tiller. growth stage : 13, 21

(d) Six fully expanded leaves, main shoot and four tillers, Pseudostem erect. growth stage : 16, 24, 30

Cereal plants drawn
by Hilary Broad.

(c) Five fully expanded leaves,
main shoot and three tillers.
growth stage : 15, 23.



(e) Eight fully expanded leaves,
main shoot and three tillers,
Two nodes detectable.
growth stage : 18, 23, 32

method, the new, eighth edition of the Weed Control Handbook (Fryer and Makepeace, 1976) retains the first definition, counting leaves only when the next is visible. Herbicide evaluation has always been related to this definition and the introduction of a more sophisticated one for farm use would be impractical. It is to be hoped that this definition will achieve universal use with a consequent alteration to the notes accompanying Zadoks' code. In the meantime, wherever leaf number is given, the method of leaf counting should be added.

Leaf sheath measurements

The term 'fully-tillered stage' appears in the instructions for the use of most winter wheat herbicides. However, few herbicide specialists and fewer spray operators can define this stage with confidence. In our studies at the Weed Research Organization we have detected no relationship between tiller production and apical development nor was there any definable peak in tiller number. Leaf number also proved to be an inadequate guide to apical development. This is, perhaps to be expected in a crop where ear initiation is dependant on the duration of low temperatures during the winter (vernalisation) and increasing day length in spring (photoperiod). Moreover, counting the leaves of winter wheat plants in the spring is difficult because earlier leaves have begun to die and shrivel.

Our studies have, however, suggested a practical and reasonably accurate criterion by which to predict apical development in winter wheats. The length of the leaf sheaths measured from ground level, where the shoot changes colour from white to green, to the uppermost ligule (Fig. 1d) proved to he highly correlated with the stage of apical development (Tottman, in prepn.). This applied, in three years, to both main shoots and the first two primary tillers and to a range of twelve varieties selected for their dissimilar growth habits. It now needs testing over a wider range of growing conditions. On the present evidence, it already serves as an improvement over the existing criterion, the 'fully-tillered stage' and is, therefore, being incorporated in the eighth edition of the Weed Control Handbook

When the leaf sheath length reached 3-4 cm, double ridges, the first appearance of the spikelets (Fig. 2), were recorded on the stem apices. In a parallel experimen a growth regulator herbicide mixture was found to cause abnormal ears at harvest when applied before the main shoot leaf sheath lengths reached 5 cm. Later applications were well tolerated by the crop.

Leaf sheath length could provide a quantitative distinction between the easily-confused stages 4 and 5 of Feekes and Large or G and H of Keller and Baggiolini's scale (Fig. 1d). It is unfortunate that Zadoks et al should amalgamate these two stages, whose distinction is critical to safe herbicide timing in winter wheat. They make a single stage, 30, defined as pseudostem erection. It would seem preferable to ignore Zadoks' comparison with the Feekes-Large scale and to re-define pseudostem erection as the stage at which the main shoot leaf sheath length of a winter wheat plant exceeds 5 cm.

The jointing stage

The apparently straightforward definition of the onset of jointing, by the appearance of the first node on the main stem, is also open to different interpretations. When a node can be seen on a plant growing in the field, several further nodes are likely to be found if the plant is removed from the soil and the lower leaf sheaths peeled back. The beginnings of stem elongation can be felt amo the leaf sheaths a week or more before the appearance of nodes on the undisturbed plant. The drawings by Large and Keller and Baggiolini show an intact plant with a node clearly visible and this is probably the definition adopted by the workers who framed our herbicide recommendations. In view of this uncertainty it is, perhaps, fortunate that spraying herbicides too late does not always cause crop damage.

Zadoks et al attempt a more objective definition of jointing in their reference to the number of nodes detectable. However, the detection of a slightly swollen node before it reaches ground level, even when the outer leaf sheaths have been removed, can still be a matter of judgement. It might, therefore, be better to count nodes only when they can be seen or felt, on the main stem of the plant, above ground level. Under normal spring conditions this should be closely related to the stage of apical development (Faris et al 1969). The length of the leaf sheaths may also provide a guide to the onset of jointing. In our studies the detection of nodes, above ground level, coincided with the appearance of anther and carpel initials in the developing spikelets and a leaf sheath of about 10 cm. (Tottman, in prepn.).

Variations of growth stage within a crop

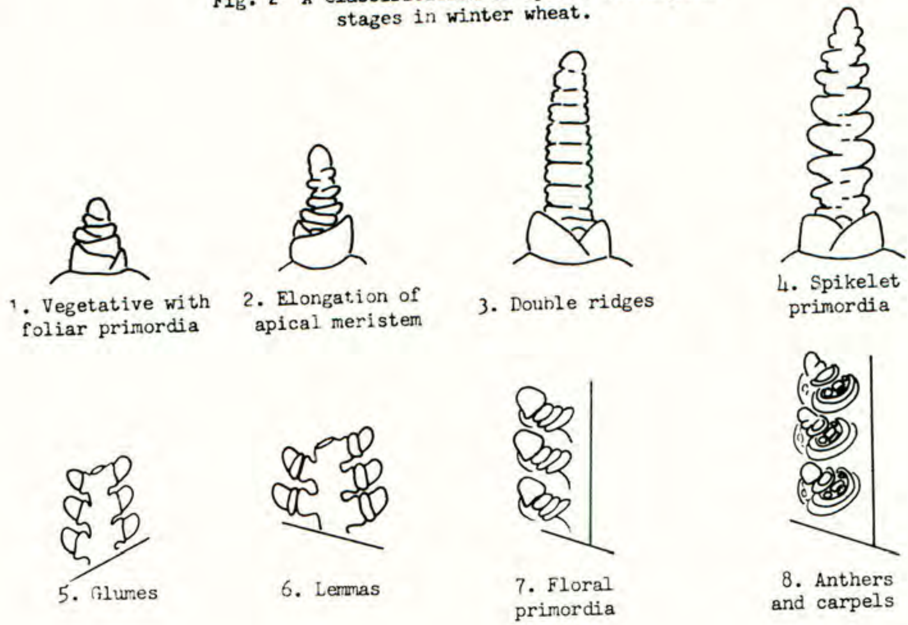
For the purposes of timing chemical and cultural treatments a crop is often assumed to be a homogeneous population of equally developed tillers. This is never true. There is always considerable variation between plants within a crop and between the tillers of a single plant. Unpublished data from our winter wheat growth stage studies at the Weed Research Organization show a wide range of apical development stages between plants and among tillers, even in small samples from uniform field plots. In mid-April, when the succession of new types of primordia is most rapid, the main shoot apices of randomly collected plants of Cappelle varied from the initiation of spikelet primordia to the appearance of lemmas (Fig. 2). The inclusion of tillers widened the variation considerably. When spikelets were differentiating on the apices of most main shoots some second primary tillers had only reached the stage of apical elongation. Even when nearly all the main shoot apices were producing anther and carpel initials, some second tillers were still at the double ridge. This variation can be reflected in the response of the crop to a growth-regulator herbicide, the tillers remaining sensitive after the main shoot has reached the stage at which ear deformities are unlikely (Friesen and Olson, 1953). In our plots the plants produced an average of just under two fertile ears but the number varied from one to four. The final ear population must, therefore, have contained a proportion of second and even third tillers. When lower seed rates are used or more plant mortality occurs, tiller production and survival may be greater, leading to an even wider spectrum of growth stages.

Considerable care should, therefore be taken in sampling crops or plots for growth stage assessments. To determine the correct time to apply a herbicide a number of plants from several representative areas of a field should be checked and account taken of any differences in growth stage caused by uneven moisture or disease levels. Zadoks' code is better applied to individual plants than to populations. The correct procedure in sampling a reasonably uniform cereal experiment is to collect, at random, as many plants as practical, to describe each in accordance with the code and then to use the mode and range of these observations to characterise the population.

Classification of apical development

While leaf number and leaf sheath length can give rough practical guidance to the stage of apical development, any detailed studies of spray timing still require plant dissections and a record of apical appearance. Moreover, while these relationships between external and internal development may hold good in field grown crops under the conditions of a normal British spring, they are unlikely to apply to plants grown in artificial environments (Faris et al, 1969; Andersen 1955). Methods of describing apical stages have varied as much as the growth stage keys used to describe the plants external appearance. The classification we have used in our experiments at the Weed Research Organization is illustrated in Figure 2 and owes much to earlier studies by Bonnett (1936), Andersen (1954) and Barnard (1955). The stage of development of an apex was categorised on the basis of the type of primordia most recently differentiated. During the early stages of ear formation the most advanced middle spikelets determined the category by which the meristem was described, although upper and lower spikelets often lagged several stages behind (Kirby, 1974). To achieve uniformity and valid comparisons between research reports requires the adoption of a system of apex classification, preferably in association with Zadoks' code and using similar notation.

Fig. 2 A classification of apical development stages in winter wheat.



RECOMMENDATIONS

The cereal growth stage key recently proposed by Zadoks, Chang and Konzak (1974) provides a unique opportunity to standardise growth stage descriptions and so improve comparisons between the results achieved by different experimenters. Its use in all future herbicide experiments must be encouraged.

Herbicide recommendations for the farmer should make use of the descriptive terms used in Zadoks' code. For example, 'MCPA' should be applied on winter cereals from pseudostem erection to the detection of the first node and on spring cereals after the fifth leaf is unfolded but before the first node is detected. Such a statement could be accompanied by small clear drawings to clarify the definition of the terms used. Growth stages of wild oats (Avena spp) can be specified in the same way.

The code does, however, have certain drawbacks for the herbicide user. Leaf numbers might be more easily counted by adopting the definition of a main stem leaf currently used in the Weed Control Handbook: that is counting an expanding leaf when the tip of the next becomes visible. Leaf sheath extension seems to give a useful guide to the development of the young ear and would provide a better criterion by which to judge spray timing in winter wheat than the presently used 'fully-tillered stage'. It is, therefore, suggested that Zadoks' stage 30, pseudostem erection, might be re-defined by a measure of the leaf sheath lengths. The jointing stage, too, might be defined more objectively if only those joints, detectable by sight or touch, above ground level are counted.

When timing of herbicides requires an accurate assessment of crop growth stage some attempt must be made to encompass the range of growth stages present in the crop or experimental plot by extensive sampling.

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WEED RESEARCH REQUIREMENTS IN DEVELOPING COUNTRIES

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Summary The problems of introducing modern techniques, especially herbicides, to the small-scale tropical farmer are largely economic and educational, but research has a part to play in seeking cheaper, simpler and safer treatments. The research already in progress in developed agriculture will eventually provide the answers to some of the problems but a number of particular examples are described of problems peculiar to the developing countries which need special attention. These include the development of herbicides for the minor tropical crops, simpler application techniques, herbicides suitable for application after dry planting, cultivation systems for perennial weeds, crop varieties resistant to parasitic weeds, improved weed control in minimum cultivation situations and in ground cover legumes. Finally there must be emphasis on integration of different weed control methods making full use of the available hand labour.

We are concerned today with one basic question - why the weeding practices on small-scale tropical farms cannot be immediately upgraded by the use of modern techniques. And my own task is to consider whether it is for lack of research that progress is not more rapid.

We should not, of course, take it for granted that there is a universal need for improved methods. In certain types of cropping and climate there may not be serious losses from weeds under the traditional farming system. There is, however, little doubt that inadequate weeding results in serious yield reductions on most farms and there are further indirect losses which cause us to think in terms of perhaps 25% overall loss due to weeds in this class of farming (Parker & Fryer 1975).

By "modern techniques" we generally mean the use of herbicides and this will be the main assumption in this paper, but mechanical and other methods will also be discussed. At present, although no statistics are available, it is unlikely that herbicides are being used to any significant extent on farms smaller than five hectares in most developing countries with the possible exception of rice farms in the Philippines where granular herbicides have been introduced with considerable success. Yet farms less than five hectares comprise a very large proportion of the cultivated area in most tropical countries, and improvement in yields on these farms could have a large impact on world food production.

The problems associated with such small farming units can, of course, be approached from a socio-political angle and resolved to some extent by collectivisation as under communist regimes in Eastern Europe, China, Cuba etc, but discussion of this type of solution would be somewhat outside the scope of this session.

I would like firstly to consider the question of direct transfer of established techniques from large-scale to small-scale farming, where the crop and weed problems are comparable and technical solutions already exist. I shall then consider the problems that are more specific to the tropics and for which techniques may not be so well developed.

1) Problems for which technical solutions already exist

In highly developed agriculture, in both temperate and tropical countries herbicides are used on a large proportion of all the major agricultural and horticultural crops. Technically the problems are much the same on small farms as on large ones; the main crops are the same - rice, maize, wheat, cotton, groundnut - and the weeds are often the same. Is it practical for small-scale farmers to use these herbicide treatments? And if not, why not?

The answer must be no and at first sight it would seem that this has nothing to do with research. The technical answers have already been worked out and have been well proven in large-scale farming; it must be a question of economics and education.

The most obvious barrier to herbicide introduction is, of course, the economic one which we shall be hearing more of later. The cost of the herbicide creates difficulties in terms of credit availability even if it can be shown to give an economic return. Solutions have, therefore, to be sought in terms of providing credit or subsidizing herbicides for the farmer. But there is still a place for research in that there is a need to find cheaper treatments wherever possible and so make the economics more nearly acceptable. Ideally new cheaper herbicides are needed but it is doubtful whether any new herbicide can ever be cheap in view of the enormous costs of development involved. It is important, therefore, not to forget the older compounds and the ways in which their performance might be improved by formulation, additives and better application. These are important fields of research which are already of great interest to developed agriculture and are likely to receive increased attention in the future (eg Glass 1976). The importance of these approaches, however, are even greater for developing countries and they should receive particular attention.

The second good reason why herbicides are not being used on the small farms is because of the risks of damage to the crops. Technically the herbicides are safe enough, but only if they are accurately applied, at the right dose, to the right crops at the right time. These are problems which the next speaker is no doubt going to discuss in detail from the point of view of education and extension, but there is again a place for research aimed at finding more highly selective treatments. Such research will in any case be conducted for the benefit of developed agriculture and the small farmer will hopefully eventually benefit.

An alternative to new herbicides is the development of antidotes which protect the crops and so improve the selectivity of existing herbicides. The value of this approach will depend to a great extent on the attitude of government regulation agencies. If antidotes are "anti-toxicant" perhaps they do not have to be regarded in the same light as pesticides, but as synthetic chemicals applied directly to crop plants they must presumably be subject to much of the same toxicological and environmental studies and hence might not be significantly cheaper to develop than new herbicides.

2) Application problems

Although improvements in application methods will be of great interest in developed agriculture, as a means of improving the efficiency of herbicides, these methods do not need to be particularly simple. On the other hand the vital need for the small-scale farmer is the simplification of application methods. In the context of developed agriculture, granular herbicides have rarely shown any technical advantage over spray formulations and are usually slightly more expensive. Furthermore the application of granules to large areas involves yet another expensive piece of machinery. Granules do, however, offer several important advantages to the small farmer, which could outweigh some moderately increased cost. They do not normally require dilution, so eliminating one source of error on the part of the farmer - though preparation of home-made granules on the farm as described by Zahran et al (1976) later in this session brings back this step. The density of herbicide deposit can be seen on the ground so reducing the risk of very uneven application and local overdosing. Most importantly they can be applied by hand or by very simple spreader so reducing the cost of application equipment.

In transplanted rice granular formulations of most herbicides, when applied into the water after transplanting, perform at least as reliably as liquids. In upland situations, on the other hand, there have often been disappointing or unreliable results from granular formulations. There has been relatively little systematic effort to determine the factors causing this unreliability - herbicide concentration, granule size, distribution, soil moisture, soil type etc, nor the type of herbicide most suited to use in this form. I believe that a slightly volatile compound is likely to give the most reliable results under typically varying soil moisture conditions. Some of the compounds normally requiring incorporation because of their volatility might be found to be applicable to the soil surface in granular form and so do away with the need for incorporation into soil which is a procedure beyond most small-scale farmers. Much more research is needed on this topic, which is of very special interest to developing countries.

The new hand-held spinning disc sprayers (eg Bals 1975) have some of the advantages of granular application, in simpler dilution and less water requirement, but more research and development is needed to produce more rugged machines which perhaps use man-power and mechanical propulsion rather than the batteries and electric motors which have proved a little troublesome so far. There is also the need for more flexibility in the width of the spray swathe so that it can be used for inter-row work.

3) Crops peculiar to tropical situations

So far we have considered the problems of a simple transfer of herbicide technology from large-scale farming to small-scale, assuming the same crops and the same weeds, but there are, of course, a number of crops in tropical farming systems for which herbicides have not yet been developed or for which the range of herbicides is still very limited. Even sorghum is not well catered for and there are many others including millets (*Pennisetum*, *Eleusine* and *Panicum* spp.) cowpea (*Vigna* spp.) chickpea (*Cicer arietinum*), pigeon pea (*Cajanus* spp.), kenaf (*Hibiscus* spp.) jute (*Corchorus* spp.), cassava (*Manihot esculentus*), yams (*Dioscorea* spp.), taro (*Colocasia antiquorum*) etc for which there is still a need for more herbicide screening and hopefully, the development of completely new compounds, though the economics of development of a herbicide specifically for one of these "minor" crops are not too favourable.

A further problem is the common practice of mixed cropping which seriously limits the range of herbicides which could be selective. It is in these situations that there may eventually be a particular use for herbicide antidotes.

4) Special weed problems

It has been argued above that the weed problems are generally similar in the small and large-scale situations and it could even be said that they are generally easier on the small-scale farms where herbicides have not yet resulted in the selection of tolerant species. There are, however, some particular species which present special problems in the tropics, and for which solutions are still lacking. The most outstanding example is the parasitic genus *Striga*, which affects millions of hectares of sorghum, millet and other cereal crops in Africa and Asia. There are no herbicides with reliable selectivity and research is needed to accelerate the development of resistant varieties of the crops involved. Such efforts have been made in the past on a local basis but the new international institute ICRISAT

(International Crops Research Institute for the Semi-Arid Tropics) is now taking the lead in an intensified effort which should provide benefits in Africa as well as India.

Of the other parasitic weed problems Cuscuta spp. should be relatively easily kept under control by hand removal under intensive small-scale farming conditions. Likewise the mistletoes, although serious in large-scale citrus estates and forestry, can best be controlled by intensive hand pruning. The Orobanche species on the other hand are just as difficult as Striga and there are localised problems in many developing countries, affecting tobacco, rape and various vegetables in India, Pakistan, the Middle East and parts of the Caribbean and South America. Again chemical approaches have so far not been very successful and more attention is needed to the selection and development of resistant varieties.

Annual weeds do not usually present problems in the early stages of the introduction of chemical methods. They tend rather to acquire importance under chemical weed control regimes, as the easier species are reduced and the more tolerant thrive. Avena fatua (wild oat) is the prime example, causing severe problems in perhaps all the major wheat growing areas of the world, especially the most "developed". Such problems are hardly yet apparent in the small-scale farming that we are considering and for those that already occur in developed agriculture research is already in progress. What is needed in addition, however, is a full realisation of the dangers of the build-up of such problems as and when herbicides are introduced and of the opportunities in developing countries for their prevention making use of the one resource of which they have a relative abundance - human labour. Herbicides must only be introduced as part of a package of weed control practices which includes follow-up hand weeding wherever this continues to be possible. Only in this way can the small-scale farmer be spared the difficulties of changing weed flora and the need to change to ever more sophisticated and expensive chemical treatments.

Meanwhile there should, of course, be close attention to the species that are most likely to increase in this way. An important example is Rottboellia exaltata which is resistant to atrazine and related triazines and to alachlor and related amides. It tends, therefore, to build-up in chemically weeded maize and sugar cane, and in regions where it is common (including parts of West and South/Central Africa, South America and the Far East) it should be taken seriously into consideration. Penoxalin is the only herbicide at all well proven for its selective control in maize but this is likely to be expensive and perhaps there are ways of using some of the older aniline herbicides as cheaper alternatives. There are, of course, a great many other potential weed problems which should be seriously considered on a local basis before they build-up rather than after. Important examples include the wild and red rices, and Ischaemum spp. in rice.

The perennials are not a general problem in small-scale farming because they have not been encouraged by the use of herbicides, but there certainly are problem species which cause very extensive and regular losses, such as Imperata cylindrica, Cyperus rotundus and Cynodon dactylon. I. cylindrica is readily controlled in large-scale field crops by deep ploughing but persists in many peasant farming situations (as well as in larger scale plantation cropping). Government tractor-hire services are a theoretical answer but have a number of disadvantages. The new "snail" project, based on simple winch operated equipment deserves further development as a tool for deep dry season cultivation not only for Imperata but also for Cyperus rotundus, Cynodon dactylon and other troublesome species (Muckle et al 1973). There are, of course, herbicides for some of these perennials but they are mostly very expensive, even by the standards of large-scale farming and economic control of perennials is a problem requiring the integration of various cultural, mechanical, chemical and biological methods. Such integrated approaches have to be adapted to local conditions and, therefore, require local research effort, including biological studies of the weeds themselves on a local basis.

5) Special climatic problems

An important difference between temperate and tropical farming is that the temperate farmer is usually waiting for increased temperatures and drier soil conditions before he can plant, whereas the tropical farmer is usually waiting for rain. For various reasons it would be best if the tropical farmer could have his crop planted "dry" and ready to germinate as soon as the rains come. One of the reasons he does not use this technique is the big flush of weeds that occurs with the first rains and the need to control these before he plants. Ideally he needs a herbicide which could also be applied dry and which could be relied upon to retain its activity for varying periods of very hot, dry conditions. Systematic study is needed to determine which herbicides in what forms and by what means of application are most likely to provide the necessary reliability.

6) New cropping systems

The examples of weed control problems and methods considered so far have all been applicable to the existing crop husbandry practices of the peasant farmer. Weed research can, however, be a very important component in the development of new agronomic systems - for instance in the control of weeds in systems of reduced cultivations and multiple cropping, and in the increased use of ground cover legumes.

The international agricultural research institutes (IITA, ICRISAT, IRRI & CIAT) are all now putting great emphasis on cropping systems and the simultaneous integration of a range of new practices leading to increased efficiency and productivity within the limitations of the peasant farmer's situation. An example from the Philippines is the effort by IRRI towards growing two crops in the wet season rather than one. Traditionally the first 8-10 weeks of the rainy season are wasted while the paddies get sufficiently saturated and flooded for the transplanting of rice. If a direct-drilled short-period rice crop is sown dry before the rains begin it can be harvested in mid-season and a second transplanted crop still obtained. This practice, however, will prove very difficult without the means of controlling prolific weed growth in the direct sown rice and of destroying weed growth and the remains of the first rice crop and preparing land rapidly for the second crop.

This is just one example of the place of minimum cultivation techniques which are at least as important to the tropical farmer as to his temperate cousin. Deep cultivations are not only very difficult for the peasant farmer with limited power, but they may also tend to damage soil structure and encourage erosion.

In West Africa it is felt not only that soils should not be cultivated but that they should also be protected from direct damage from sun and rain, by mulching (Lal 1975). Old crop residues and weeds may provide the necessary mulching material but this is often excessive or else is completely destroyed by fire. Allowing some weeds to grow early in the season and then destroying these by a herbicide such as paraquat is one answer, but another being explored by IITA, is the use of a living mulch of low growing legume, such as *Desmodium triflorum* which not only protects the soil surface but also fixes nitrogen to the ultimate benefit of the crops. *D. triflorum* may not be the ideal species being perhaps too low-growing and not sufficiently competitive with weeds but there are likely to be alternative species which have the right characteristics. In any case these living mulches will need some help in establishing in competition with weeds and there may well be a need for herbicides for this purpose. The use of ground-cover legumes is of course, already an established practice in plantation crops in many developing countries and the practice is likely to increase as the cost of nitrogen fertilizer increases. There is, therefore, likely to be a need for more systematic information on the possibilities for selective chemical weed control in such legume crops.

CONCLUSIONS

It can hardly be said that it is lack of research which is the primary bottleneck in the transfer of modern weed control technology to the small-scale tropical farmer. Education and extension are, I believe, much greater difficulties with economics a further problem. Research could, however, make contributions which would ease the educational and economic problems so that we arrive at treatments which have the necessary characteristics of safety, simplicity and cheapness.

I have outlined some of the types of research which are needed to achieve these objectives. Some of it is already in progress in developed countries because the needs of developed agriculture are the same, but I have also attempted to identify the ways in which the objectives of research for the small farmer differ from those for large-scale farming. Such research will not be the whole answer. There will still be the educational and economic problems to be solved but I hope that the following speakers will give us some grounds for optimism that these problems are not insuperable. There is in any case a need for research to be geared very closely to the educational and economic realities of the situation and although herbicides are so obviously the simplest answer to the researcher in the developed country, they have to be regarded almost as the last resort in the thinking of the tropical agronomist. It is not acceptable for the weed research effort in developing countries to be geared only to herbicide testing, though such testing is necessary to clarify the possibilities for use of chemicals.

It is often argued that the most vital research is that aimed at proving the need for improved weed control methods, and it is suggested that the exact competitive effects of different weeds at different periods of crop growth must be studied and the benefits of removal at different times. A few such studies may be valuable to convince the farmer how much yield he is losing as a result of bad weeding, and it may regrettably be necessary to produce local evidence to convince administrators of the importance of weed control and the need to finance weed research efforts. In general, however, it is not difficult for the experienced weed researcher to identify those situations in which weeds are clearly interfering with a farmer's productivity. The extent of the losses can quite easily be demonstrated in the course of experiments on control measures and not too much of the scarce weed research effort should be diverted into merely proving the need.

Above all is the need for integrated research effort - integration of different methods in the control of specific problems (making the utmost use of the hand-labour) and the integration of efficient weed control practices into new cropping systems. The international agricultural research institutes are setting excellent examples in such approaches and it is to be hoped that national research organizations will follow their lead. Although the regional institutes may demonstrate the feasibility of some new techniques in their particular localities there will be a need to adapt such techniques to a great diversity of subtly varying conditions in each country and, of course, the possibility of different techniques being exploited under particular local conditions.

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REACHING TRADITIONAL FARMERS WITH IMPROVED WEED MANAGEMENT IN LATIN AMERICA

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Summary New weed control technology has not been adopted by traditional farmers. Frequently they desire to use improved weeding practices but the lack of adequate education and development programs makes it difficult to change from traditional methods. The establishment of model farms to test and demonstrate improved production systems, including new weeding practices, in regions of small farmers is proposed. The training of key individuals in weed management is also essential. Concepts which must be taught to traditional farmers include all sound agronomic practices which increase crop competitiveness, the importance of preventative weed control measures and the importance of timely weeding. If herbicides are recommended, traditional farmers must be taught to calibrate a sprayer and to understand concepts of rate per unit area, pre-emergence activity, herbicide selectivity and residual action.

INTRODUCTION

Major advancements in food production have taken place on large farms in the past 25 years. The adoption of new varieties, fertilizers and pesticides are only three examples. Modern Latin American farmers are as proficient in growing crops as their counterparts in temperate climates. But there is a huge difference between the production systems used by modern farmers and those of traditional farmers. In many respects farming practices have changed only slightly on the small-scale farm, in spite of rapid progress in other sectors.

In particular, weeding practices on traditional farms are still based on the use of the hoe and the machete. Frequently weeding is done too late to prevent serious losses from competition, and simple weed prevention practices are seldom employed.

Why has the small farmer not improved his weeding practices? Although the answer is complex and varies from country to country, one important reason is the lack of concerted effort in development and education.

Weed Control and Traditional Farmers

At the onset, I would like to propose the following definition of weed control as appropriate for the traditional farmer: "the maintenance of weed populations at levels which do not cause economic losses". While advanced farmers try to keep fields weed free during the entire growth cycle, peasant farmers do not perceive this as necessary or feasible. With this defined objective, let us explore how to reach traditional farmers with improved weeding practices.

It would be wrong to assume that the only "new technology" we have to offer traditional farmers consist of chemical weed killers. In fact, there are many situations where this alternative is not the best one. Improved varieties, high quality seed, fertilizers, adequate soil preparation and pest control all produce vigorous crops which compete well and dominate many weeds. With only the introduction of crop management practices, weeds would be less of a problem. Likewise, the importance of preventative measures and timely weeding practices must be demonstrated and emphasized.

What evidence do we have to indicate that small farmers would adopt new weed control techniques? This can best be illustrated by citing examples of how they are now adopting new practices. In Colombia, some traditional farmers weed maize by applying paraquat with shielded nozzles after crop emergence. In the only documented study to date, Rogers and Meynan (1965) found that 65% of the peasant farmers in four Colombian villages adopted 2,4-D between 1944 and 1963. In Perú, many upland rice farmers in the Amazon area use 2,4-D for broadleaf weed control. Some Honduran small farmers use a mixture of paraquat and 2,4-D in mature maize, and then edible beans are planted prior to maize harvest. The nature of the mixture indicates a need for education since there is no apparent justification for mixing contact and systemic herbicides. Sugar cane is grown by small farmers in Bolivia and they have been taught to successfully use pre-emergence herbicides. In Colombia, several cassava farmers are experimenting with the use of herbicides, and others are comparing the use of chemical energy in no-till systems to the traditional slash and burn techniques.

Increased urban migration in all developing countries tells us that the drudgery of spending 50% or more of your life fighting weeds causes rural youth to seek employment opportunities in the cities. For example, in Colombia the number of small farms is disminishing. From 1960 to 1970, there was a 7% reduction in the number of farms less than 10 ha in area, and an increase of 15 and 19% in the number of farms with 20 to 50 and 50 to 200 ha, respectively (Kornfield, 1974). If weeding could be done more efficiently, farm life would be more appealing and fewer people would migrate to overcrowded urban centers. However, it is important to note that more than 20% of the total number of farms in Colombia in 1970 were "farms" of less than one hectare. Obviously, these farmers must work for additional income outside their own plots, which includes hand weeding. Therefore, it may be that more efficient weeding practices on some small farms will increase rural unemployment and urban migration by displacing these hired laborers.

The Adoption Process

In the developed world, the adoption of new methods and ideas follows a defined and understood process. Modern farmers pass through the stages of awareness, interest, mental evaluation and field trials as they adopt new technology (Rogers, 1962). Such models of adoption may be non-functional in the developing world where the challenge is to effectively communicate new technology to traditional farmers. A contrast of modern and traditional farmers (Table 1) shows that in all respects traditional farmers face more difficulties to incorporate change into existing systems.

The "trickle-down" process in which first the innovators, then the early adopters, the majority and lastly the late adopters, accept an innovation, is valid only for modern farmers. For example, the adoption of hybrid maize and the use of 2,4-D in Iowa, U.S.A., took 9 and 2.1 years, respectively, (Rogers, 1962). Within the context of their current constraints, innovative traditional farmers exist, but they are not being reached by current educational and development programs. (Some exceptions exist where active rural development or cooperative establishment programs are underway, but these activities affect only a handful of the total population.) Industry feels that the traditional farmer is too limited by his educational level and lack of capital to be a potential client. And government ministries and agricultural institutes are trying to kill elephants with rubber bands, when one compares the size of the problem they face to the limited inputs of manpower and money going into areas of traditional farmers. Nevertheless, nearly all Latin American countries are committed in principle to helping subsistence farmers, and their present efforts cannot be dismissed.

A frequent mistake is the attempt to transfer technology to traditional farms without adequate field testing under these varied conditions. In one region of Guatemala for example, fertilizers were an obligatory component of the credit package given to maize farmers. Yet the farmers did not apply fertilizers, insisting that it was a waste of money. Only several years later did field research trials in the area prove that the farmers were right: maize did not respond to the recommended fertilizers. Before we "educate" traditional farmers and "extend" new technology we must be sure that our new alternatives are appropriate to his environment: agronomically, economically, and socially.

What Must Be Done

If it is true that the bridges linking the modern farmer with change agents (governmental or commercial) and research groups are infrequent or non-existent to most traditional farmers, what should be done? Also, what are some of the hurdles that have to be overcome by education and development before major changes can be expected? One urgent need is to train more extension personnel. Rice (1971) estimated the ratio of farm families to extension agents in the Andean zone to be 10,000 to 1; the ideal is thought to be 500 : 1.

While this situation must obviously be changed, there are several reasons why achieving a 500 : 1 ratio in Latin America is neither feasible nor desirable. (1) The cost would be exorbitant for any country. (2) Extension agents are not as important in the communication process to peasant farmers as they are to advanced ones. Rogers and Meynan (1965) found small farmers consulted the farm store operator five times more frequently than the extension agent when seeking information of 2,4-D (Table 2). (3) Social, economic, and cultural differences between the extension agent and the traditional farmer make him less effective in developing countries. (4) The geographical area involved is often vast and of limited access due to poor roads. (5) There is a great lack of university graduates to train. Byrnes and Byrnes (1971) note that there are approximately 1000 new agricultural graduates each year in Latin America and the number of farmers is 115,000,000. In the United States alone there were more than 9000 graduates in 1964 and the number of farmers is much smaller.

Education and development programs must teach and demonstrate the following: (1) Sound agronomic practices adapted to local conditions and incorporated into realistic packages for traditional farmers. (2) The importance of timely weeding. (3) Means of preventing the introduction of new weed species and the spread of existing ones.

If herbicides are recommended to traditional farmers, the following hurdles must be scaled through educational activities.

(1) Sprayer calibration. Most herbicides have limited selectivity and the risk of crop injury if excessive rates are applied may be great. Small farmers who have applied fungicides and insecticides are accustomed to mixing a certain amount of product in each sprayer tankful of water and applying it, regardless of the area covered. This cannot be done with herbicides, except with post-emergence applications where the recommendation can be made on a percentage basis.

The method used by the Bolivian small farmers growing sugar cane mentioned previously may be applicable to other areas as well. They are all taught to measure the same area and to adjust their walking speed and pressure until the tankful of 20 l of water is applied to that area. In this way each one mixes the same amount of product(s) in each tankful, standardizing the application on all farms.

(2) Concept of rate per unit area (i.e. kg/ha). This goes hand in hand with sprayer calibration. At best traditional farmers are familiar with application on a percentage basis and the concept of a kilogram or liter per hectare is foreign to them.

(3) Concept of "pre emergence". As with preventative medicine, preventative chemical weed control can be a difficult concept for traditional farmers to grasp. It would be easier to teach the benefits of post-emergence products since farmers can see the problem in their fields. One demonstration should convince them of the effectiveness of pre-emergence applications.

(4) Concept of "hormone herbicides". The first weed killers introduced in Colombia were 2,4 D and 2,4,5-T (Rogers and Meynan, 1965). Many farmers believe that all other products behave similarly. Also, only one negative experience of crop injury due to drift, volatility or a poorly washed sprayer after the application of hormone compounds makes it difficult to convince farmers to try other crop herbicides.

(5) Concepts of selectivity and residual activity. The fact that the same herbicide may be safe only in certain crops is not obvious to small farmers since they may apply other pesticides in several crops. After obtaining excellent weed control in maize with atrazine, one Ecuadorian farmer used it the next season in beans; as would be expected the bean crop was killed. If potentially long lived products are recommended, the possibility of harmful carry overs to rotation crops must be stressed.

(6) Safety measures. All pesticides are poisons. For personal, family and environmental safety, proper handling, application and storage procedures must be taught.

All the above points concern only the farmer. If progress is to be made, a tremendous effort must also be devoted to educating those involved in all phases of development and decision making in government and industry of the importance of improved weeding practices (Davidson, 1974). Nothing is gained, for example, if weed losses are reduced and production increased, if there are inadequate markets or storage facilities. Or perhaps, farmers are willing to change their weeding methods but there is no credit to purchase the necessary equipment or inputs. An integrated attack on production-limiting factors has the best potential pay-off.

The Future

Certainly the answer to the question "Are there adequate methods and resources for the effective introduction of new weed control techniques to farmers" is a resounding no.

What do we need to do to change this? Extension and rural development personnel must identify the true problems facing small farmers. All too often the "expert" arrives with the textbook answer to only textbook situations. When his suggestion is not followed, he concludes that the farmer is resistant to change, when in reality the farmer has not been offered a better solution to his problem (Whyte, 1975). The farmer's ability to survive with his present system means he is quite knowledgeable about farming, and if a new experience give positive results, his acceptance and improved production is guaranteed.

An improvement in the competence of agronomists and others in weed management is urgently needed. Present extension and development people should be trained in the principles and practices of weed management. Short courses of a one to three week duration can give them the confidence needed to teach and demonstrate better methods to farmers. These individuals should in turn train cooperative leaders, rural development personnel and farm store operators and in this way multiply their area of influence.

It is normally desirable that a complete new combination of practices which is more productive than the present ones be taught to traditional farmers (Wortman, 1974). If the only message given is that farmers should do a better job of weeding, little progress will be made. Equally important, the farmer must be shown and not told how to do a better job of producing food. Likewise, the "showing" must not be done by an "expert" who is culturally, socially and economically different than the farmer.

Model farms should be chosen in regions of rural development programs on which new technology is tested locally. Feasible weed management practices and the losses due to weeds should be demonstrated. Ideally local farmers should be involved in helping plan the trials. They may even offer one of their fields to be used as a demonstration area.

Universities should make weed management a required course, as entomology and plant pathology have been for years. Those which do not offer weed courses should be convinced of the importance of this practice in agricultural production systems and of the necessity to train graduates competent in weed management skills.

Those activities which will increase communication between institutes, credit groups, government organization, universities and the industry are to be encouraged. Development is a complex and intricate process, and only when all interested parties are informed and cooperating will success be assured.

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Table 1. Comparison of several characteristics between traditional and modern farmers in Latin America.

CHARACTERISTIC	TRADITIONAL FARMER	MODERN FARMER
Income	Low	Mod-high
Capital investment	Low-none	Mod high
Access to credit	None-limited	Many
Farm size	Small	Med-large
Quality of land	Poor-good	Good-excellent
Access to markets	Difficult	Easy
Access to information	None-limited	Many
Literacy	Low	High
Risk acceptance	Low	Mod-high
Socio-economic orientation	Subsistence crops	Cash crops
Cropping patterns	Polycultures	Monocultures
Energy sources	Manual and animal power	Mechanical

Table 2. Effectiveness of extension agents and farm store personnel as communication sources by adoption stage for 2,4-D in Colombian villages (Rogers and Meynan, 1965).

ADOPTION STAGE	PERCENTAGE UTILIZING EACH SOURCE	
	Extension Agent	Store Personnel
Awareness	7.5	36.6
Interest	6.9	27.2
Evaluation	3.1	11.6
Trial	8.3	41.2

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OPPORTUNITIES AND LIMITATIONS IN THE USE OF HERBICIDES IN DEVELOPING COUNTRIES

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Summary The present paper expresses the views of the industry on the constraints applying to the use of herbicides in developing countries. Yields of farms are greatly below their potential, and one of the principle causes is the ineffective control of pests, diseases and weeds. Figures relating to the economics of herbicides are available from many parts of the world, and although difficult to compare, interesting opportunities and more so, an urgent need to use herbicides are obvious. The most important restraints which limit the introduction and use of herbicides in developing countries in space and time are considered to be:

a) Financing of Agriculture and Economics of Herbicides,
b) Education and Training,
c) Psychological Barriers,
d) Mechanisation,
e) Fear of Unwanted Side Effects,
f) Fear of Under-Employment,
g) Poor Recommendations for Use and for Product Application,
h) Harmonisation of Pesticide Legislation.

INTRODUCTION

An Englishman would introduce this paper with the appropriate pun. But since it is difficult to match the talents of a British speaker, it is preferable to do things the Continental way and to start with a motto. I should like to quote the Potash Institute of North America: Those who grow our food cannot walk backwards into the future.

The introduction of herbicides in developing countries is sometimes felt to be very limited and slow in relation to the large sales of herbicides in other parts of the world. On closer examination, it is apparent that such a general statement does not reflect the true situation. If we consider that the first timid applications of phenolic herbicides on cereals in Europe were made only about 40 years ago (Fryer and Evans, 1968. Table 1), and if we take into account the fact that in the last decade stringent pesticide legislation has come into force almost all over the world, the progress made in the developing countries is far from negligible. On the contrary, there is a remarkably high level of technical knowledge in the various research stations as well as in projects and other, larger undertakings.

Table 1

Some Events in the Development of Herbicides

1930	Britain	substantial acreage of cereals sprayed with sulphuric acid
1932-33	France	DNOC used for weed control in cereals
1941-42		discovery and development of MCPA and 2,4-D for weed control in cereals
1957		SIM and ATR for weed control in maize

Fryer and Evans, 1968 (excerpt)

OPPORTUNITIES

Mankind is seeking ways to prevent malnutrition and achieve economic stability. Yields from farms are greatly below their potential, and one of the principal causes is the ineffective control of pests, diseases and weeds.

The FAO Indicative World Plan, IWP (Graham, 1969), an ambitious survey of the future of world food production, was completed in 1969. The plan is largely concerned with developing countries (or Zone C nations) with a predominantly agricultural economy. 85 out of every 100 people born between now and 1985 will live in Zone C. Assuming there is no change in either calorie intake or food quality, this would require Zone C nations to increase their food supply by over 80%. IWP makes intensification of agriculture the cornerstone of its entire plan.

Therefore, as worded by Adam (in Gunn and Stevens, 1976), agriculture in developing countries is relied upon

firstly, to provide subsistence for a substantial segment of the rural and urban population;

secondly, to earn foreign exchange through the export of a small number of agricultural commodities - 'cash crops' - produced either on individual farms or under cooperative arrangements;

thirdly, to save foreign exchange by import substitution.

Today already twice as many people are fed and clothed on little more land than in the past. If this land were properly tilled, seeded, fertilized and irrigated, and if the crops were protected from diseases, pests and weeds, considerably more food and fibres could be obtained from the world's present cultivated area.

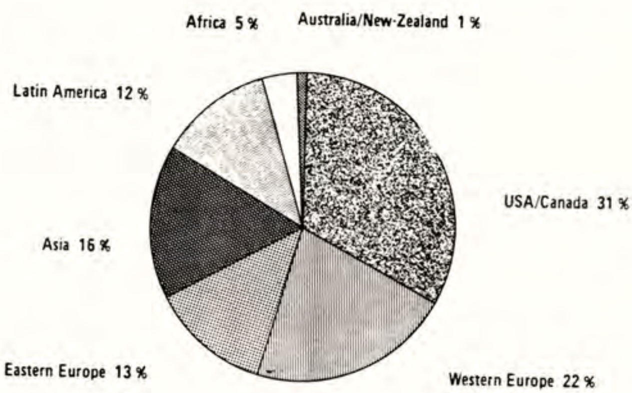
The average pre-harvest loss of food crops in developing countries is generally estimated at about 30 to 50% of the harvested crop. An important part of the loss, although less apparent than the one due to insects, is yield reduction because of competition by weeds for space, light, water and other nutrients. Surprisingly enough, the general recognition of this fact is even rather recent in regions with more developed agriculture. Therefore, it is not astonishing what JAGADISAN (1975), for example, reports from India, where in 1975, herbicides were used on less than 5% of the treatable area. This is attributed to the fact, that the farmers' need have not been identified by the authorities and that it has not been ascertained what category of farmers can, will or should use herbicides. Fortunately a remarkable progress in developing countries is predicted for the near future by Adam (ibid). According to him, within the period from 1975 to 1977 herbicides are expected to account for some 10 per cent of the total pesticides used. For high-yield varieties this supply will be extremely important.

On a world level, Kradel (in International Conference, Stirling, 1973) predicts a similar trend for herbicides as for insecticides. In countries with a highly developed agriculture, such as Germany, herbicides are the chief crop protection products. Here they account for over 50% of the total, as against only 5-6% for insecticides. Although the use of insecticides in tropical countries will remain dominant, the above forecast is a challenging one relative to herbicides.

In this context Cramer (1975) has made a thorough survey of the worldwide consumption of pesticides.

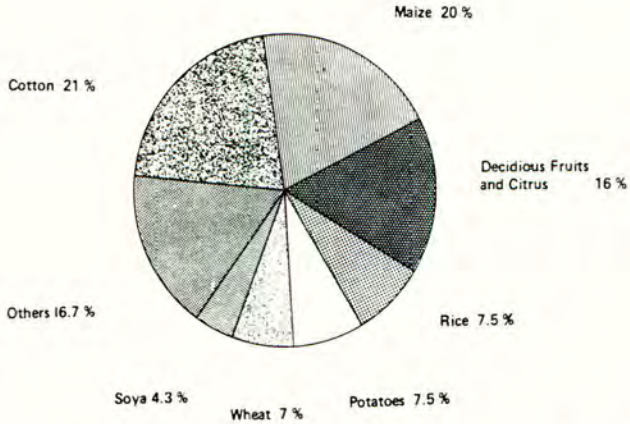
- The world pesticides market, divided into regions, shows that up to the present the high-population regions have the smallest supply of agrochemicals at their disposal (Fig. 1).

Fig. 1. AGROCHEMICALS – WORLD MARKET BY REGIONS (Cramer, 1973)



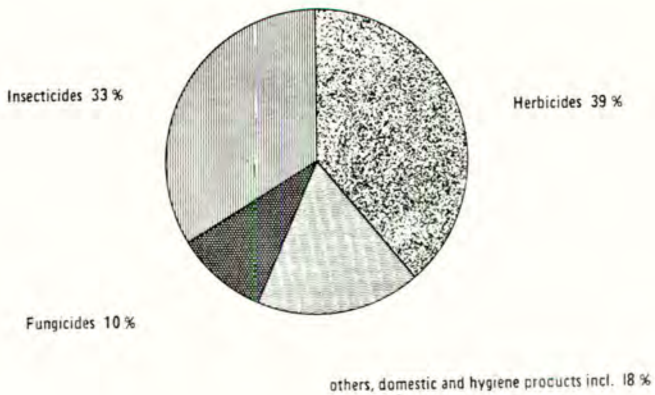
- Analysed according to cultivated plants, the world pesticide market shows a similar distribution. Rice feeds 60% of the world population but only accounts for 7.5% of the world agrochemicals consumption. The largest percentage is used for cotton and corn (Fig. 2).

Fig.2. AGROCHEMICALS – WORLD MARKET BY CULTIVATED PLANTS (Cramer, 1973)



- An interesting comparison can be drawn between the groups of agrochemicals. In this field, a new development seems to be taking place. On a worldwide basis, herbicide consumption has outgrown insecticide consumption. This is mainly due to the replacement of increasingly expensive human labor by chemical herbicides. Another contributing factor is the development towards mechanical harvesting (Fig. 3).

Fig.3. AGROCHEMICALS – WORLD MARKET BY GROUPS OF PRODUCTS (Cramer, 1973)



So which path should we take? More land and less herbicide or less land and more herbicide ? Is chemical weed control an economic proposition at all?

Although figures relating to the economics of herbicides are available from many parts of the world, they are difficult to compare because costs depend very much on the degree of mechanisation of the farms as well as on the cost of local labour. Herbicides benefit the farmer by enabling him to overcome peak manpower requirements and to plant larger areas, this in itself contributing to a rise in income. In other words, herbicides make labour more productive.

Three typical examples may demonstrate the benefit from the use of herbicides.

From Senegal (SODEVA, 1975) it is reported that the use of a pre-emergence herbicide in groundnuts eliminates the work peak between seeding and first hand hoeing by prolonging the time between the two operations by 13.5 days. The benefit is said to be twofold. Time becomes available either for thinning corn and sorghum or for increasing the area planted with groundnuts two and a half times over. Furthermore, it was observed that in view of such a good crop, farmers tend to improve the quality of their input with regard to seed treatment, soil preparation etc.

Figures from India (Shukla and Maurya, 1970) demonstrate that the net return is superior to that obtained with hand weeding when herbicides are used in four major crops, namely corn, rice, sugarcane and wheat (Table 2).

Table 2

Expected Gross and Net Return from Crops

CROP	GROSS RETURN *	NET RETURNS		
		Unweeded	Hand *	Weedicides
Maize	960	-45%	420	+19% (800 cc 2,4-D/ac) +13% (750 g SIM/ac)
Paddy	1600	-52%	1050	+ 5% (1,6 l. propanil/ac)
Sugarcane	1960	-61%	1180	+ 9% (800 cc 2,4-D/ac) + 6% (1200 g SIM/ac)
Wheat	1200	-42%	715	+ 7% (400 cc 2,4-D/ac)

Shukla and Maurya (1970), adapted
* Rupees/acre

The third example of an encouraging success is reported by Mann (1975) who worked with a USAID/Oregon State University Wheat Research Team in Turkey in 1975. While the greatest gains came from combining weed control with other elements in a recommended package of practices, when only chemical weed control was added to traditional practices, a gross return of 4.4 Turkish Lira was obtained for each

Lira invested in weed control.

Commonly accepted experience shows that in terms of return on investment, herbicides rank third to insecticides and fertilizers as a form of agricultural input. In other words, herbicides should not be introduced before insecticides. On the other hand, the expenses for fertilizers are only justified if their benefit is not brought to nothing by a luxuriant growth of uncontrolled weeds. In case of rice for instance, when Monocharia is present, its ability to absorb nitrogen not only removes any benefit to the crop, but actually harms it directly by further competing for space and light (Table 3).

Table 3

Effects of nitrogen level and weed competition on yield of rice

Amount of Nitrogen (kg/ha)	Type of weed infestation	Weed weight kg/ha	Yield of rice tons/ha
0	clean weeded	0	4.5
60	no weeds	0	5.3
120		0	6.6
0	Echinochloa crus-	127	4.4
60	galli only	232	4.0
120		285	5.5
0	E. crus-galli +	150	4.1
60	Monocharia vaginalis	326	3.1
120		573	3.5

Courtesy Dr. S. De Datta, IRRI

LIMITATIONS

After having recognized the opportunities and more so, an urgent need to use herbicides in developing countries, the question arises what circumstances are limiting their introduction so much in space and time today.

Let us start from a rather simplified scheme, by no means complete, of a pattern for the development of agriculture in developing countries with special reference to herbicides (Table 4). Obviously this scheme does not really provide the answers how to realize the development, as every step requires a tremendous and long-lasting effort. The scheme merely sketches the successive steps.

Snelson (1975) has compiled a basic list of 27 potential 'constraints' which limit the introduction and use of pesticides in developing countries. Most of them apply to herbicides, too. Under practical conditions many of the prerequisites are so interrelated that the obstacles to overcome fortunately seem to reduce themselves to a number smaller than 27. The sum of the problems is in fact a socio-economical complex, the improvement of which is a question of generations. This considerably retards the use of a technology which is available already today.

The various restraints may be summarized as follows:

a) Financing of Agriculture and Economics of Herbicides
b) Education and Training
c) Psychological Barriers
d) Mechanisation
e) Fear of Unwanted Side Effects
f) Fear of Under-Employment
g) Poor Recommendations for Use and for Product Application
h) Harmonisation of Pesticide Legislation

Table 4

Agriculture in Developing Countries

Problem	Solution
shifting agriculture because of soil fertility	crop rotation manure and/or fertilizer
shortage of hand labour	mechanisation (tools) draft animals plough
unstumped lands breakage of machinery	stumping of land introduction of cash crops
shortage of labour for manual weed control	chemical weed control
even distribution shortage of water equipment for application maintenance and repair	LV and ULV application appropriate equipment

sound, diversified agriculture, increase of standard of living

a) Financing of Agriculture and Economics of Herbicides

The main limiting factor for the use of herbicides in developing countries is undoubtedly the problem of financing the development of agriculture in general. Financial aid is needed by thousands of smallholders who are unable to produce more than a very small margin over the subsistence requirements of their families. Regardless of whether it concerns education and training, mechanisation or any other kind of input, many developing countries are caught in a vicious circle as regards increasing agricultural production, and it is difficult for them to achieve a breakthrough. This demands extra capital, which, and although difficult to obtain, is an indispensable requirement for agricultural development. Only the aid of International Organisations and National Development Funds endowed by various countries as well as Rural Credit Schemes on a Government basis can help them to get off the ground.

In the opinion of Ansell (in Gunn and Stevens, 1976) a very difficult problem is to devise ways of using available funds to help individual farmers and of organizing credit schemes that have the effect of raising agricultural output instead of worsening the situation by obliging farmers to pay large amounts of interest. Snelson (1975) expresses the view that in the past agriculture has often been neglected to second priority projects not directly related to agriculture. Furthermore, where funds are lacking, priority is frequently given to insecticides. This is an obvious policy, since weeds can still be removed by hand while insects cannot.

The relationship between the actual costs of using herbicides and the value of increased yield and quality is a very complex one. It is estimated that in developed countries, with the high costs of associated inputs such as labour, mechanization and land, the cost of the pesticide input probably amounts to no more than 5% of the total costs of production, so that the benefit resulting from the use of herbicides far outweighs their costs. On the other hand, in the developing countries the costs of related inputs are relatively low. Under these conditions the cost of the pesticide input may be as high as 40%, and therefore reaches a very critical limit.

Whittemore (1973) lists the following factors influencing the costs of pesticides:

- basic costs of chemical
- supply and demand
- transport
- trade agreements, as well as
- change of weed flora
- change of local varieties
- cessation of intercropping
- decision as to the appropriate type and local production of formulation
- lack of necessary infrastructure

He fears that together, these factors might so increase the end consumer price that the cost of treatment could sometimes become prohibitive.

Relative to the price of pesticides as a limiting factor, concern is also voiced by major agrochemical research firms. Because the increasing development costs and other difficulties have not only handicaped manufacturers by forcing them to reduce the number and the variety of new herbicides, but sometimes prices for badly needed products have risen beyond the reach of authorities and users in developing countries.

b) Education and Training

The restraints to the practice of weed control differ depending on whether they relate to peasant farmers, coops, government projects, etc. In the two latter cases plenty of expert knowledge is generally available. However in developing countries, the major crops are grown on scattered individual land holdings. Adequate technical supervision becomes difficult, if not impossible. Training in plant protection and in the proper use of pesticides must therefore be given top priority in developing regions. Notwithstanding it is estimated that only 5% of the available technical information on plant protection reaches and is actually used by farmers in developing countries.

Shortage of technically trained people and the illiteracy of most of the farmers call for a corporate effort by all agencies and industries involved. Importance must be attached to the development of proper understanding of the psychological process by which information is received and accepted by farmers.

While it is generally acknowledged that many manufacturers and distributors have made an outstanding contribution to the safe, efficient and effective use of pesticides in the region, it is suggested that industry should make a greater effort to train the user in proper pesticide handling and application techniques. The same applies to Government Extension Services. In particular the peasant farmer cannot solve the problem of how to achieve an optimum economic return on his land. This clearly falls under the competence of the Ministries of Agriculture and their Extension Services. Often the personal and material potential of the latter is limited by a lack of financial resources so that the impact of their effort is small and slow.

c) Psychological barriers

The problem is not merely one of a competition between plough and pill. Although the primary question is that of producing more food, we must ask ourselves whether we will be successful in transmitting new knowledge to hundreds of millions of new farmers and changing their way of life accordingly. The obstacles to be overcome include uncertainty and distrust of new things, the abject poverty of a large part of the population, parasitic diseases, and a lack of trained persons. If these obstacles are not removed, they seriously impede progress towards the goal and reduce our effort to a futile struggle against hunger and want. Why should a peasant farmer produce more food and animal feed than his family needs? And how can he understand why the government, because of limited foreign exchange available for the importation of pesticides, gives first priority to the production and protection of an 'export crop' on the cooperative nearby, whilst his family may be short of food? Does he understand that intercropping, which has been practised for generations and which is even recommended in some regions to combat erosion, seriously limits the introduction of chemical weed control because of the lack of multi-selective compounds? Can he realize that eight amaranthus weeds per meter row of maize reduce the yield by 27%? (Table 5). Moreover, with very few exceptions the selectivity of herbicides is not unlimited. Unskilled use often results in either damage to the crop or unsatisfactory weed control. This kind of accident may create long-lasting setbacks to both local authorities and farmers.

Table 5

Effect of Amaranthus spp. on maize yield (10 cm wide bands)

Amaranthus plants/meter	Yield loss, % 2 year average
1	6
2	14
4	15
8	27
40	38

E.L. Knacke, ILSU (USA)

d) Mechanisation

As for mechanisation, a very fundamental change is urgently needed before the introduction of herbicides is justified. It does not primarily concern tractors and other complicated farm machinery. What is needed and is widely lacking are dibbles, long-handled hoes, scythes, ploughs, draft animals etc. Where more sophisticated machinery and spray equipment are available, even if they are of a simple kind, the main problem is often the lack of spare parts and the endless limitations it creates. Local restrictions and time required for formalities concerning the import of spare parts are obstacles which are sometimes difficult to overcome.

e) Fear of unwanted side effects

It is to be hoped that the overreaction to the danger of pesticides that sometimes occurs does not unfavourably influence the evaluation of agrochemicals by the competent people in the developing countries. The hazard from pesticides arises more from ignorance, carelessness and culpable negligence than from the inherent toxicity of many widely used materials. In order to avoid this we certainly have ahead of us a vast education and information programme which we have clearly neglected for too long.

f) Fear of under-employment

The problem of unemployment is a complex one and each situation must be analysed separately. It is not believed that the use of herbicides will generally increase unemployment, and in the medium term the contrary may become true. According to Ansell (ibid) the problem of under-employment does not exist under favourable circumstances as every man-hour that becomes available will immediately be invested and many workers are free to produce things other than food. On the other hand, however, it is known that in Tanzania out of 14 million people less than 1 million are earning a salary. The others live on farms and will still have time for hand weeding, until the economic situation has somewhat improved.

g) Poor recommendations for use and for product application

The manufacturers' recommendations for use and warnings or cautionary statements on labels and leaflets must be simple, printed in the local language, supported by schematic drawings where appropriate.

Similar requirements exist for application equipment. The quality of application greatly influences the efficacy of the product. If badly applied, even the most potent preparation is ineffective. Conventional spraying methods require a large volume of liquid. But water may be scarce, and its transport is slow, tiresome, and often costly. With the aid of new spraying methods the quantity of water can be reduced. In extreme cases special formulations even allow the product to be used undiluted without water. For special cases limited lifetime application equipment may be suitable. However good the results obtained with such type of equipment for concentrate or even waterless spraying for low volume application, the knapsack sprayer still remains a very valuable piece of equipment which allows a satisfactory compromise between high volume, ULV and granular application. The idea of using granules is very attractive because there is no need for either equipment or water. Nevertheless, the use of granular formulations is greatly limited by problems associated with their production and logistic distribution.

Small packages are the only units peasant farmers can afford. What they buy is the portion for one application on a small field. An additional advantage of the small units is the possibility of preventing wrong dosages, particularly if the prepacked portion is adjusted to the volume of the sprayer. Unfortunately, small package units are well known for their high cost, and in addition they are often subject to higher local taxes than the bulk product.

h) Harmonisation of pesticide legislation

Generally speaking, the registration of pesticides does not limit the use of agrochemicals in developing countries. Nevertheless, countries importing agricultural goods require local registration or at least stipulate residue tolerances for a chemical even if it is not used in the country itself. This may lead to the application of regulations at a level which is not commensurate with either the technical or the economic situation of the country where the crop is grown. But these regulations, however difficult it may be to conform with them, are justified in the interest of the consumer.

Foxlee (International Conference, Stirling, 1973) emphasizes that standards for residues are essential and that concessions will be necessary. In this connection it will be important not to set standards militating against developing countries, but rather to encourage them as primary producers. A committee of the Codex Alimentarius is endeavouring to achieve worldwide acceptance for the residue tolerances on harvested goods proposed by FAO and WHO specialist boards. Experts from FAO, supported by the pesticide industry through its trade association 'Groupement International des Associations Nationales de Fabricants de Pesticides' (GIFAP), are elaborating criteria for international acceptance dealing with the physical and chemical specifications of the products. Efforts to achieve harmonisation are also being undertaken within the European Economic Community. It is clearly of great importance to food-producing countries that there should be worldwide acceptance of the maximum residue limits proposed by the Codex Committee. It would be erroneous to charge the registration authorities of developing countries with impeding the import of agrochemicals. Industrial countries often insist on evaluating all aspects such as efficacy, side-effects, safety and quality of a given product themselves, and virtually ignore registrations effected in other countries. By contrast, developing countries are usually more realistic in this respect: As a rule, they acknowledge the attested registration from an important industrial country as a guarantee for the safety and innocuity of a product and its quality with respect to its physical and chemical properties; further testing can therefore be limited to local suitability and efficacy trials.

WHO SHOULD DO WHAT

The present paper expresses the views of the industry on the constraints applying to the use of herbicides in developing countries. By way of a conclusion, the opinion of a representative of the pesticide industry in a developing country is of particular interest. The view, recently expressed by Jagadisan (1975) with regards to India relates to the question of 'who should do what', and calls upon seven different groups to accept the responsibilities summarized below:

<u>University Scientist</u>

- set priorities
- obtain answers to important questions
- inform regulatory agencies
- solve farmers' weed problem
- know government and indutries plan regarding product availability etc.

<u>Extension Officials</u>

- not to be afraid of herbicides
- adopt enlightened attitude as to benefits of herbicides
- imaginative information programmes

<u>Policy Makers</u>

- understand that there are no safe chemicals but safe applications
- no emotional statements
- not to act as inflatory agent through measures such as high rates of import taxes, multi-point sales taxes, octroi levies, indirect duties on package material

<u>Industry</u>

- abandon attitude of selling products to make a few rupees
- solve farmers' problem and create long-term viable markets

- solid market development
- education of farmer

Public

- demand higher standard of quality, e.g. no wild oats in wheat or barnyard grass seeds in rice

Farmer

- adopt aggressive attitude
- accept education with regard to undertaking extra operations at busy times, or extra input if it is likely to increase the crop yield

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THE ROLE OF HERBICIDES IN HIGHLY MECHANISED CASH ROOT CROP PRODUCTION

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INTRODUCTION

Traditional systems of root crop production have a high hand labour requirement. The development of effective automatic and semi-automatic planting and harvesting machinery for potatoes; and for sugar beet the achievement of monogerm seed and the pelleting process for sowing it through efficient precision drills, paved the way for reduction in hand work. But the key factor was the concurrent discovery and development of effective pre-and post-emergence herbicides. It is now possible to grow sugar beet, potatoes and some other root crops with no hand labour at all other than that required to operate the specialised machinery and spraying equipment.

In the United Kingdom all this has happened since the early 1960's; in 1961 only 5% of sugar beet, and by 1963 only 1% of potatoes, were treated with herbicides. The first post-emergence herbicides for sugar beet, phenmedipham, appeared in 1968. Herbicide usage then increased very rapidly until by 1975 98% of the beet crop received herbicides either as a single application or, more commonly, in a planned sequence of pre- and post-emergence applications (BSC 1975). Progress in usage of herbicides in potatoes has been rather slower owing to the greater opportunity for mechanical post-planting weed control; the situation is now fairly stable with about 70% of the maincrop acreage treated, a large proportion with the bipyridil contact herbicides either alone or in assocation with residuals (Hampson and Taylor, 1974 Taylor, 1976). Perennial grass weeds can now be controlled by soil incorporation of TCA prior to sowing sugar beet, and EPTC prior to planting potatoes.

The most highly mechanised farms generally have the least labour but this can achieve high work rates allowing timeliness of seedbed preparation, sowing and harvesting. The general standard of management, particularly of weed control, must also be of a high order, since if chemical weed control fails no recourse to hand work is possible. When sugar beet is precision drilled at the final plant population there are no excess plants to allow thinning by predators or pests or through herbicide damage. Conditions for establishment must therefore be as near optimal as possible; herbicides must be selective for the crop, correctly chosen and applied at the right rate for the weed flora and soil type; the overall plan for weed control must include a back-up programme which can safely be used if weather conditions and the pattern of weed emergence limit effective action of residual pre-emergence products. Compatibility of herbicides and other pesticides must also be ensured.

Some mechanical inter-row hoeing is still needed in sugar beet on soils where capping is a problem. Hoeing also reduces the cost of herbicides by allowing band application. Inter-row cultivations can also be used to place residual herbicide, for example, trifluralin, along the beet rows to provide more lasting weed control for late emerging weeds and in particular Chenopodium album. In all field crops the best that chemical weed control can do is to contain the situation until vigorous crop competition takes over. Success therefore depends on the farmer providing the conditions for herbicides to be used and work effectively; too often the herbicide is blamed for poor weed control when in fact the fault lies in the way in which it was used.

PLANNING THE EFFECTIVE USE OF HERBICIDES

Freedom from weeds may be necessary to avoid interference with harvesting, the contamination of produce and the return of viable seed to the soil, but competition from weeds during crop establishment is usually of primary importance and must be prevented. In order to achieve this should the herbicide programme adapt to farming practice or the husbandry programme be planned to offer more opportunity for effective weed control? Often the solution will be a compromise, but much can be done by better planning of cultivations and seedbed preparation.

First it must be asked whether complete weed control throughout the life of the crop is necessary. Work on sugar beet at Nottingham University (Scott et al, 1974 & 1976) indicates that something less than complete control of annual weeds may be commercially acceptable. They have shown that judged only by final yield, effective control of annual weeds in sugar beet is only essential between 4-8 weeks after sowing. Similar results are reported for cabbage by Roberts et al (1976). However, there are other considerations for example, ensuring freedom from Polygonum aviculare or late emerging Chenopodium album which would impede harvesting or seeding of Solanum nigrum which could present problems in a following crop of vining peas. Farmers do not like to see weedy crops even if these weeds are doing no harm and they will take steps to control them. Thus there can arise a conflict between pride and pocket in which pride will often win.

Although sugar beet is a very resilient crop once established, in the immature stages it is sensitive to unfavourable factors in the crop environment; the effect of these will be aggravated by any errors in herbicide technique whether in the timing of application, the dosage, the mixture or sequence. High yield requires a vigorous stand of plants at optimum density, which can attain a high leaf area by early June in order to take full advantage of the long days and high sunshine of mid-summer.

Work in progress at the Norfolk Agricultural Station has shown that certain 'cocktails' or sequences of herbicides designed to give season long weed control have an adverse effect on the beet. However the marked selectivity of metamitron and ethofumesate will go a long way towards improving safety to the crop and the further development of adjuvants may play a part. The final objective must be complete safety of the chemicals used so that obtaining completely clean crops is in no way restrictive of yield or quality. This is of particular importance in the context of attaining maximum yield, a subject currently receiving much attention for both root crops and cereals (Evans, 1976).

The presence of some weeds during the earliest phase of establishment may help to prevent serious loss of sugar beet seed and seedlings to mice, birds and other pests when the beet seedlings would otherwise be the only source of food over the whole field. These weeds must then be removed by post-emergence herbicides. On soils subject to wind erosion the presence of killed weed cover can help to prevent 'blowing'. In potatoes a dense cover of small weeds can be very effectively removed by contact herbicides just as the crop begins to emerge.

Rotation and Cultivations Both rotation and cultivations can affect weed numbers and associations. Baldwin (1972) referred to cereal crops as 'cleaning' crops. Studies at Brooms Barn have shown that the use of herbicides in the two previous cereal crops reduced weed numbers in sugar beet seedbeds from an average of 103 to $49/m^2$ in May, but cultivating or spraying the cereal stubble had no effect on weed numbers. Cultivation did influence the composition of the weed flora; - less Stellaria media and Poa annua but more Polygonum aviculare after ploughing than after tine cultivation (Rothamsted 1975). It is common experience in the UK that reduced cultivations for cereals, especially in long runs of winter sown crops, have led to considerable increase in Alopecurus myosuroides and other annual grasses. A. myosuroides is also appearing in very early sown spring cereal crops and on lighter soils outside its more normal habitat of the heavier and wetter soils. Thus as a direct consequence of cereal husbandry practices, A. myosuroides could become a weed of early sown sugar beet, a situation which is reported already to have arisen in other European countries. An analogous situation arises in connection with the problem of annual weed beet, which is referred to again later. This weed is associated with close rotation of beet crops and the cultivation system influences seed dormancy.

Thus we see that while basic cultivations may now play a less critical role than formerly in direct weed control, they can have an important influence on the weed spectrum. Care must be taken to see that in seeking reduced cost or increased speed of cultivations, for example by replacing ploughing with tine cultivations, we do not create a weed problem requiring heavy expenditure on herbicides for all arable crops in the rotation.

Seedbeds For the success of both crop establishment and weed control by pre-emergence herbicides there must be a satisfactory seedbed. This means the elimination and avoidance of cultivation - or plough-pans, absence of excessive clod, a fine firm level tilth and adequate moisture. In normal UK winters the greatest tilth forming factor is frost but this tilth can be lost by over-frequent or excessive working in spring. There is, therefore, a move towards preparation of seedbeds in autumn which will require only minimal working in the spring; this avoids both loss of moisture and the formation of clods and gives a firm tilth into which the seed is sown. 'Fluffy' seedbeds give neither good seed/soil moisture relations nor effective residual herbicide action. Of course, on soils where capping is a problem excessively firm seedbeds may not be acceptable either. Autumn seedbed preparation may also offer opportunities for the application of herbicides in autumn or winter, possible using granular formulations, but so far these have not proved very successful.

Even when seedbeds and weather conditions are not ideal for effective residual herbicide action, the use of a pre-emergence herbicides as part of a planned sequential programme will weaken weed seedlings which can then be treated with post-emergence herbicides over a longer period and more advanced stages of growth.

Recent dry springs have demonstrated the need to sow sugar beet seed into moisture even if this involves drilling deeper than is recommended under ideal conditions. This slightly deeper seed placement can reduce the risk of crop damage following heavy rain from the more marginally selective pre-emergence or pre-sowing herbicides.

On some soils, especially highly organic soils, incorporation of the herbicide can improve weed control but may also require an additional operation leading to loss of moisture. The addition of scraper blades to drill mechanisms to move clods and stones from the row into the inter row gap, allows more even depth of sowing, resulting in more regular seedling emergence, and improves the surface conditions for band applied residual herbicides.

The problem of wind erosion on some sandy and organic soils can be alleviated by allowing weed cover to develop or by sowing rye on an autumn prepared seedbed. The weeds or rye are then killed by a contact herbicide before or shortly after sowing the beet (or other crop) direct into the "sward". The root mat stabilises the soil and the killed vegetation provides shelter which prevents surface erosion. This shelter may also enhance the growth of the establishing crop.

Another variation in establishment technique which is currently receiving attention is the direct drilling of sugar beet into the undisturbed stubble of a previous crop. This involves the use of contact herbicides before or at drilling, backed up by appropriate residual and contact treatments to deal with the weed flora which develops. Where blowing is a problem this technique is of particular interest, but it seems likely that to ensure good root penetration by the beet, subsoiling would be required either for the preceding cereal crop or on the stubble.

Investigation is required into the contribution which irrigation at comparatively low rates of about 20 mm could make to improving sugar beet seedling emergence and assisting herbicide activity in dry spring. The certainty of adequate moisture being present might allow a lower dose of herbicide to be applied which would be an advantage with those which are marginally selective.

Residue Problems Herbicides must not only be effective in controlling a broad spectrum of annual weeds but they must also degrade to harmless residues in the crop and soil before harvest (Schweizer, 1976). The problem of slow degradation has become particularly important in the recent hot dry summer. Residual herbicides are widely used in root crops and some products have the requirement that ploughing must be carried out before the next crop is sown. Even so in unusually dry years like 1976 there may need to be some extension of the period during which it is unsafe to sow the next crop. Thus the choice of a particular herbicide can restrict freedom of cropping or cultivation and in the case, for example, of metribuzin, the need to plough after potatoes may aggravate the groundkeeper problem, which is referred to later. Sometimes these considerations may be an overriding disadvantage, making the use of a particular herbicide undesirable irrespective of its efficiency for weed control in the crop.

Seed "advancement" The technique of advancing seeds to achieve rapid germination and field emergence has been pioneered by Heydecker et al (1975). Early work on sugar beet at Nottingham University, Norfolk Agricultural Station and by ADAS shows considerable promise. More rapid and synchronous emergence can be obtained from "advanced" seed and with closer size range of the beet seedlings more precise timing of post-emergence (and possibly contact pre-emergence) herbicides can be assured. This vigorous start should also accelerate the competitive ability of the beet by allowing it to attain a complete cover earlier in the season. There are, however, still technical problems to be overcome in the handling of "advanced" seed, for example, the pelleting process. Similarly, fluid drilling is in the development stage and may yet have a part to play in ensuring improved and rapid establishment of beet and other crops.

Annual weed beet Annual weed beet plants have been a problem on the Continent for some years and in 1975 it was realised that some fields in England had become seriously infested. The problem was first reported by Longden (1974). Individual case histories show that in some fields infestation extends back over 2 or 3 cycles of beet production, but generally at a fairly low population level until 1975. These annual beet plants can arise from accidental cross fertilisation of the beet seed crop with the wild beet Beta maritima, and also in low numbers as a result of of segregation within the complicated genotypes of some modern monogerm varieties. The seed shed by 'normal bolters' can also germinate to give a weed beet problem (Rothamsted 1975). Where the problem already exists and there is a reservoir of 'weed beet' seed in the soil, it does not make much difference how it arose, but for the future it is obviously very important to avoid new infestations. There will have to be careful siting of sugar beet seed crops both in UK and other seed producing countries, and seed lots will have to be carefully screened for the presence of annual 'bolting' types. The prevention of seeding of 'bolters' in commercial sugar beet crops is essential. Trials have shown that glyphosate applied by rogueing glove or bar equipment may have a place, the alternative being cutting or physical removal by hand; the time of cutting is very important.

Control of weed beet is also required in other crops grown in fields used for sugar beet. A limited survey by ADAS in 1976, a very dry season, showed that seedlings of weed beet do occur in various crops and in cereals are more sensitive to the ioxynil types of contact herbicide than to hormones. Studies on the control of weed beet in cereals are the subject of a later paper at this Conference (Longden et al, 1976). The problem has been - and will be - aggravated by closer rotation of sugar beet crops and may also arise when 'no ploughing' systems of growing winter wheat after sugar beet result in overwintering populations of beet crowns or roots which grow and set seed in the following year.

More weed beet seedlings have been found in sugar beet fields than in cereal crops in 1976, suggesting that the type of seed bed prepared for sugar beet and spring sowing favours their germination and establishment. Shallow autumn cultivation may encourage the germination of wild beet seed, which can then be destroyed by contact herbicides, whereas ploughing buries a proporation of the seed to a depth where it becomes dormant and from which it will be turned up again in subsequent years to germinate, grow and seed in other crops.

The likelihood of finding a herbicides which will be selective for weed beet in sugar beet seems remote, thus control within the sugar beet crop will have to be achieved using a combination of cultural methods and contact herbicides. Stale seedbed techniques may be particularly useful. In fields with known heavy infestations it may be essential to omit at least one cycle of sugar beet.

Potatoes - some special considerations There is more opportunity for weed control by post-planting cultivation in potatoes than in sugar beet (albeit with some risk of reduction in yield) and this has limited further expansion in the use of herbicides. If shallow cover to encourage quick emergence is wanted or there is insufficient depth of tilth at planting to form the final ridge, the immediate application of residual herbicide is not appropriate. Rounded or flat-topped ridges allow the most effective residual herbicide activity; often this ridge shape is not achieved. Dry springs have limited the effectiveness of residuals and increased interest in post emergence application. Care must be taken when using mixtures with contact herbicides, usually paraquat, not to delay application beyond 10% crop emergence.

Recent developments have centred on the use of metribuzin, especially post-emergence, on highly organic soils where the comparative ineffectiveness of other residual herbicides makes it particularly useful. Unfortunately the variety Maris Piper, which because of its resistance to pathotype A of potato cyst nematode is widely grown on fen soils, is sensitive to post-emergence application of metribuzin. Work has therefore been carried out in the incorporation of metribuzin in an attempt to improve its residual activity. This is giving encouraging results and development work is proceeding (May, 1975).

Metribuzin has limitations in the control of Galium aparine and Avena fatua so there remains an opportunity for the development of a further post-emergence herbicide with efficient action against these weeds and no varietal tolerance problems.

Groundkeeper potatoes At the 1974 Conference a series of papers was presented on "crops as weeds" and this year we have a further paper by Lutman (1976) on the problems of controlling groundkeeper potatoes. These are generally well suppressed by early sown cereal crops, but in laid cereals, sugar beet, peas, carrots and some other crops they can be a major nuisance. For potato crops they pose the triple hazard of being a reservoir for virus diseases, increasing the risk of build-up of potato cyst nematodes and are rogues in seed crops. Because most arable crops are sensitive to the herbicides which control potato groundkeepers, their control within a crop situation is extremely difficult (Lutman, 1975). Metoxuron can be used in mixture with linuron in carrots but generally the use of herbicides must depend very largely on opportunities arising to spray the foliage of the volunteer potatoes with glyphosate or aminotriazole after the 'cover' crops have been harvested. Some effective results have been obtained by directed sprays in growing crops. The need to plough after using certain potato herbicides is an aggravating factor and the availability of herbicides, especially post-emergence ones, which do not have this limitation would be helpful. Some potato varieties which seed freely can give rise to potato seedlings but these are fairly well controlled by herbicides.

In potatoes and some other crops oil seed rape can be a nuisance weed especially through late successions of germination giving rise to plants which herbicides applied pre-emergence of the crop are not sufficiently persistent to control (Hughes, 1976).

Desiccation of potato haulm Potato harvesters operate most efficiently when the potato haulm has died back either naturally or after it has been killed by a desiccant. All existing desiccants have the draw-back either of being corrosive to equipment and operators' clothing, being Scheduled under the Health & Safety Regulations or are liable to cause vascular staining of the potato tubers if they are applied in dry soil conditions. There is obviously a place for an improved desiccant.

Herbicides in swedes and turnips Swedes are grown as a cash crop in some areas. Very successful weed control can now be obtained by the use of pre-emergence herbicides notably trifluralin, and by precision drilling it is now possible to grow crops of swedes and turnips without any hand work at all. There is still a lack of an effective post emergence herbicide.

LOOKING AHEAD

A similar paper in four years time will no doubt record further changes in production techniques and these must always take account of the need and opportunity to use herbicides safely. Plant breeders, too, must continue to test their material under various pesticide regimes, but so long as the pesticides themselves are subject to fairly rapid obsolescence and replacement the plant breeder faces a difficult task.

Herbicides are now international 'Big Business' which has accelerated the search for new chemicals and formulations. The cost of launching a new product for a major crop is now so high that all aspects of its use and effects must be evaluated before it is marketed. This requires trials which are carried to final yield at both weedy and weed free sites to allow assessment of the effect of the herbicide on the crop. The effects (if any) on quality factors such as taint of produce, sugar content and juice purity of sugar beet must also be determined. Interactions with other herbicides and pesticides normally used in the crop must also be assessed - and here lies difficult ground when the products come from different manufacturers.

New techniques of application, for example controlled droplet application, may allow increased efficiency and reduced rates of application of water or product, thereby helping to keep the cost of chemical weed control in check. But it will still be the careful planning of rotation, basic cultivations, seedbed preparation and all the other factors which contribute to a vigorous crop which will create opportunities for herbicides to be used with safety and greatest economic effect.

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THE USE OF LOW RATES OF LENACIL IN AN EFFECTIVE AND SAFE PROGRAMME OF WEED CONTROL IN SUGAR BEET

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Summary Lenacil at 400 g a.i./ha as a pre-drilling incorporated treatment provided 57.7% weed control when applied on its own. Post-emergence treatment with phenmedipham following the reduced pre-drilling lenacil increased control to 91.3%. Limited data indicated that two applications of phenmedipham alone provided 69% control. The addition of lenacil to the second phenmedipham treatment improved control of late germinating weeds.

Résumé Le lenacil utilisé sous la forme d'une poudre mouillable en présemis incorporé assure un contrôle des mauvaises herbes de 57.7%. Une application de postémergence de phenmedipham effectuée après le traitement au lenacil à dose réduite permet d'augmenter le contrôle et d'obtenir une efficacité de 91.3%. Quelques résultats d'essai montrent que deux applications de phenmedipham sans traitement de présemis manifestent une efficacité de 69%. L'addition de lenacil au second traitement de phenmedipham permet de limiter l'importance des levées tardives de mauvaises herbes.

INTRODUCTION

Until recently the standard method of weed control in sugar beet was the application of pre-emergence soil-acting herbicides. While control was not complete it was sufficient to supplant mechanical hoeing and cultivation. High plant populations precluded the risk of significant reductions in crop numbers that these compounds could have caused.

The advent of selective post-emergence herbicides have increased the level of weed control achieved. This has coincided with a desire to drill to a stand, requiring better crop selectivity and to improve weed control further due to the cost of hand hoeing.

In the past our recommendation for lenacil was to apply a single application of 800 g a.i./ha without allowance for any post-emergence treatment. Under such conditions crop safety and efficacy were only partially satisfactory.

The advent and widespread usage of phenmedipham provided the opportunity for a new approach to sugar beet weed control. Therefore the aim of the trials described in this paper was to define a sequence of treatments using lenacil and phenmedipham which would provide good selectivity and a high level of weed control.

METHOD AND MATERIALS

Experiments have been carried out in France during 1975 and 1976. They were located in the sugar beet areas of the Paris Basin and North France on a range of typical soils.

Trials were laid out on a randomised block design with three to six replicates. Each plot was subdivided into two or three parts, enabling evaluation of treatments at the three distinct timings. Plot size was 3 m x 15-25 m long.

Application was by Knapsack sprayer at 4 bars. Spray volume was 500 l/ha.

Pre-drilling compounds were incorporated by means of a double pass with a normal Dutch tine harrow or by a single pass with a kongskilde harrow.

The commercial formulation of lenacil was used namely 80% wettable powder. Rates were 400 and 800 g a.i./ha. Post-emergence treatments were carried out with the standard phenmedipham liquid formulation containing 16.7% a.i. at 1000 g a.i./ha and occasionally 670 g a.i./ha. Mineral oil was added to the phenmedipham on the basis of 3-5 l/ha.

Pre-drilling treatments were applied just prior to drilling. The first post-emergence phenmedipham treatment was carried out between the cotyledon and 2 leaf stage of the beet. The second application was at the beginning of the 4 leaf stage.

Assessments for crop safety and weed control were carried out at regular intervals after treatment.

Selectivity was scored on two counts :

(a) Visual scoring on crop vigour on the following basis:
 0 = no sign of phytotoxicity

10 = total destruction of beet

Under normal conditions 3 corresponds to the commercially acceptable limit of phytotoxicity.

(b) Seedling counts on 30-40 m lengths of sugar beet in each plot.

Efficacy was assessed on a percentage basis compared to the untreated control plots. While 0 represents nil effect, 100 indicates complete weed control. Complete lists of weeds were drawn up for each trial so that effects of treatment on individual weed species could be determined accurately.

RESULTS

Results will be covered under two broad headings:

Selectivity Crop safety has been evaluated in 15 trials carried out during 1975 and 1976.

Table 1 summarises the visual scoring on crop vigour in those trials carried out during 1975 and 1976 where lenacil at 400 and 800 g a.i./ha was followed by phenmedipham at 1000 g a.i./ha in comparison with pyrazone plus phenmedipham.

Table 1

Crop safety of different treatments (g a.i./ha)

Pre-drilling treatments			Lenacil 400	Lenacil 400	Lenacil 800	Lenacil 800	Pyrazone 3200 (1975) 2400 (1976)
1st foliar application phenmedipham + (Oil 2 - 4 l/ha)			---	1000	---	1000	1000
Locations							
1975	Fillières	20/6*	---	0	---	0.25	0
1975	Montemaffroy	16/6	---	0	---	5.5	0.75
1975	Aulnay	16/6	---	0	---	0.75	0.50
1976	Heurtregiville	19/5	0	0.5	0.25	0.50	1.0
1976	Warmeriville	19/5	0	1.25	0.50	2.0	1.5
1976	Betz	26/5	2.0	2.25	4.0	4.75	1.0
1976	Berneuil	25/5	2.0	2.75	4.25	6.0	2.0
1976	Boffles	13/5	0	2.5	2.0	3.5	---
1976	Bacquencount	11/5	0.5	3.0	2.0	3.0	---
1976	Cordoux	20/5	0.5	0.75	2.0	2.5	---
1976	Lumeau	11/5	0	0	0	0	---

* Date of assessment

The rate of lenacil at 400 g a.i./ha was safe and although the addition of phenmedipham decreased the crop vigour ratings, still an acceptable level of crop safety was experienced at all but one marginal site. The higher rate of lenacil alone provided reduced crop vigour at two locations and the application of phenmedipham exacerbated the situation. In fact an unacceptable degree of phytotoxicity was recorded at 2 of the 8 sites with 800 g a.i./ha and this was increased to 50% of the sites after phenmedipham had been applied. The application of pyrazone plus phenmedipham resulted in similar crop vigour scores to the standard (400 g a.i./ha) lenacil plus phenmedipham.

Table 2 summarises the beet seedling counts.

Table 2

Number of beet seedlings
(Phenmedipham + Oil plot = 100)

Pre-drilling treatment (g a.i./ha)	1st foliar application (g a.i./ha)	1975 3 trials	1976 4 trials	General mean
Lenacil	Phenmedipham + (Oil 3 - 4 l/ha)			
400	1000	99.3	96.0	97.4
800	1000	91.0	88.2	89.4
Pyrazone				
1975 3200 or 1976 2400	1000	94.3	96.0	95.3
----	1000	100	100	100

In these 7 trials the programme of lenacil followed by phenmedipham has been compared to a pyrazone followed by phenmedipham and phenmedipham alone. Compared to the untreated controls all treatments have reduced the number of beet seedlings. The 400 g a.i./ha lenacil caused an insignificant reduction (97.4 compared to 100 in the control plots) in beet numbers, the higher rate caused a slightly larger reduction (89.4). Pyrazone plus phenmedipham was 95.3.

Trials also investigated the selectivity of lenacil at 400 g a.i./ha followed by phenmediphan and then a second post-emergence treatment after the 4 leaf crop stage with phenmedipham at 670 g a.i./ha and lenacil 400 g a.i./ha.

Assessments during June and July could not establish any significant differences between treatments in terms of crop safety. It was concluded that crop safety was not a problem with such a treatment.

Efficacy Results will be considered on a similar basis to the earlier section, covering first the efficacy of lenacil at 400 and 800 g a.i./ha followed by phenmedipham at 1000 g a.i./ha and then the complete programme.

In Table 3 the results of 9 trials carried out in 1975 and 1976 are listed comparing lenacil at the two rates followed by phenmedipham and pyrazone also with post-emergence treatments afterwards.

Table 3

Weed control efficacy (g a.i./ha)

			Lenacil				Pyrazone		
Pre-drilling treatments			400	400	800	800	3200 (1975) 2400 (1976)		--
1st foliar application phenmedipham + (Oil 3 - 4 l/ha)**			--	1000	--	1000	--	1000	1000
Locations									
1975	Fillières	20/6*	42	92	70	100	85	100	63
1975	Montemaffroy	16/6	75	100	96	100	99	100	91
1975	Aulnay	16/6	35	92	60	92	69	97	86
1975	Vrigny	26/6	78	90	81	91	75	90	58
1975	Lasson	13/6	74	96	87	97	81	91	57
1976	Heurtregiville	19/5	56	88	71	85	50	80	75
1976	Betz	26/5	65	100	90	100	83	100	86
1976	Berneuil	25/5	76	93	80	96	80	100	73
1976	Warmeriville	19/5	49	71	40	80	40	78	70
Mean			57.7	91.3	75	93.4	73.5	92.8	73.2

* Date of assessment
** Rate of product

At the reduced rate of 400 g a.i./ha lenacil on its own as a pre-drilling treatment did not provide adequate levels of weed control - only 57.7%. At the previously recommended rate of 800 g a.i./ha lenacil gave 75% control, comparable to the standard rate of pyrazone.

However, the subsequent application of phenmedipham at the cotyledon to 2 leaf stage increased weed control to 91.3% (reduced rate) and 93.4% (higher rate - 800 g a.i./ha). Similar levels of control were found after applying phenmedipham to those plots treated with pyrazone at the standard rate.

It appears very clearly that lenacil at the reduced rate of 400 g a.i./ha followed by phenmedipham has provided a very satisfactory level of weed control. Phenmedipham alone, without the benefit of a preceding treatment, only gave 73.2% control.

Weeds controlled This programme has provided control of the following weeds inter alia:

Anagallis arvensis, Capsella bursa-pastoris, Chenopodium spp., Fumaria officinalis, Matricaria spp., Poa annua, Polygonum spp., Sinapis arvensis and Stellaria media. Mercurialis spp. and Galium aparine were not controlled so well.

Problem weeds In a further 9 trials the Seppic Company in 1975 and 1976 evaluated lenacil + diallate as a combination. 97% weed control was obtained by using lenacil 400 g a.i./ha in combination with diallate 1200 g a.i./ha as a pre-drilling incorporated treatment followed by an early application of phenmedipham + oil at 670 g a.i./ha + 5 l/ha. The combination of lenacil + diallate was found to be of especial value where grass weeds such as Alopecurus myosuroides and Avena spp. were prevalent.

Control of late season weeds 15 trials were evaluated 3-4 months after drilling to determine the long term effect of the programme approach. At 3 of the sites no pre-drilling herbicide was applied and the advantages of the full programme can be seen clearly in Table 4.

Table 4

Final weed control - treatment rates in g a.i./ha

Pre-drilling treatment	1st post-emergence treatment cotyledon 2 leaf stage S. beet	2nd post-emergence treatment 4-8 leaf stage S. beet	Number of trials	Mean note efficacy
Lenacil 400	Phenmedipham 670 to 1000 + (Oil 3 - 4 l/ha)*	Phenmedipham + lenacil 670 + 400	15	91.4
---	Phenmedipham 1000+ (Oil 3 - 4 l/ha)*	Phenmedipham 1000+ (Oil 3 - 4 l/ha)*	3	69.0

* Rate of product

The table shows that a reduced rate of lenacil (400 g a.i./ha) followed by phenmedipham + oil at the cotyledon to 2 leaf stage and a final reduced rate phenmedipham 670 g a.i./ha + lenacil 400 g a.i./ha provided weed control 3-4 months after drilling of 91.4%. This is compared to 69.0% control from three sites only when post-emergence treatments were applied without a pre-emergence herbicide.

Although both seasons were unusually dry weed assessments 3-4 months after drilling indicated the value of adding lenacil to the second phenmedipham treatment. There were reduced numbers of late germinated weeds particularly Chenopodium album and also Polygonum aviculare.

DISCUSSION

Weed control in sugar beet as in other crops needs to adapt to the changing cultural and economic situation and the introduction of new herbicides. Reduced manpower has increased drilling beet at wider spacings and forced growers to rely more on chemical weed control. Under such conditions adequate weed control is rarely achieved by a single herbicide treatment. A programme of weed control which involves active ingredients complementing each other has been shown to provide the answer.

At the existing use of rate of 800 g a.i./ha lenacil on its own generally does not reduce sugar beet seedling numbers. However, in conjunction with phenmedipham applied post-emergence the two herbicide treatments increased phytotoxicity to an unacceptable level. By reducing the lenacil rate by a half initial weed control was reduced but brought up to fully commercial levels by the application of phenmedipham.

It is concluded that the lower rate of lenacil while not providing adequate weed control in all cases on its own has sufficiently weakened those weeds that do emerge that subsequent phenmedipham treatment can control virtually completely.

Under normal conditions timing of phenmedipham may be critical to achieve optimum weed control. Trials established that the first phenmedipham spray could be delayed and still achieve a high level of weed control.

While earlier trials had established that phenmedipham plus lenacil at the earliest stage of application could cause problems, addition of lenacil with the second treatment provided long term control. Late germinating weeds can be a problem at harvest particularly if early to mid-summer moisture allows some late germination of such weeds as Chenopodium album enabled to germinate after hoeing.

The programme provides a high level of weed control throughout the growing season. Reducing lenacil applied pre-drilling provides crop safety on all soils and is economically very attractive. Slightly more flexibility is allowed with the subsequent phenmedipham treatment and the resulting weed control is over 90%. Adding lenacil to the second phenmedipham extends the period of control.

For growers with grass weed problems the 400 g a.i./ha rate of lenacil when combined with diallate and incorporated pre-drilling extends the spectrum to include Avena spp. and Alopecurus myosuroides.

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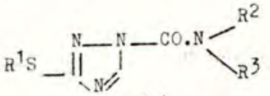
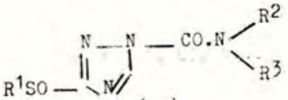
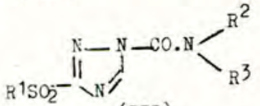
One of the most surprising features of this group as a whole is the remarkably wide variation in alkyl substitution which is possible, both at S and N, while maintaining a very high level of herbicidal activity. Further substitution of e.g. halogen or alkoxy-groups into the alkyl substituents is also possible in many cases without loss of activity.

Another early observation was that the extent of oxidation of the sulphur atom also had a considerable effect on activity, in the order:


(I)


(II)


(III)

It is interesting to note here that the 3-dialkylsulphamoyl derivatives (III, R^1 = R^4R^5N) are also highly active.

In view of the very wide range of compounds exhibiting high or very high levels of herbicidal activity, we have restricted the discussion of structure/activity relationships to compounds of structure III, in which R^1, R^2 and R^3 are unsubstituted alkyl (normal or branched-chain).

METHOD AND MATERIALS

Soil adsorption studies were carried out as follows:

25ml of a 0.4ppm solution of the compound in water were mixed with 10g of a sandy loam soil and the mixture agitated thoroughly. After settling for 5 mins, some of the suspension was decanted into a centrifuge tube, and clarified by centrifuging. The supernatant liquid (10 ml) was mixed with 1ml of internal standard solution (0.01% dicyclohexyl phthalate in ether) and 1ml of ether. After thorough agitation the ether layer was removed, dried over sodium sulphate, and transferred to a pointed tube. The extraction procedure was repeated with a further 2ml of ether, and the ether extracts were combined, evaporated, and the residue dissolved in 25 ul of 2 - propanol. A 2 ul portion of this solution was subjected to gas chromatography on a Pye model 104 apparatus (column 1ft packed with OV210 (5%) on Gaschrom Q (100 - 120 mesh) - column temperature 200° - flow rate 60ml/min). To determine the percentage adsorbed, the peak height ratio (carbamoyltriazole/internal standard) was compared with that from an extract of 10ml of the aqueous triazole solution processed as above but without the addition of soil.

RESULTS

We shall first consider the effects of varying the alkyl groups on the carbamoyl nitrogen and sulphur substituents in turn, then present the results of a soil absorption study on compounds which have performed well and comparatively poorly under glasshouse and field conditions.

a) <u>Substitution at the carbamoyl nitrogen atom</u>

For any given value of R^1, an increase in the number of carbon atoms in R^2 and R^3 up to a certain value tends to increase activity. We will first consider the case where $R^2 = R^3$. It will be seen from Table 1 that activity is at a maximum when R^2 and R^3 are propyl. The sec-butyl group clearly reduces activity.

TABLE 1

Effects of Structural Changes on Physico-chemical Parameters and Activity of Selected Triazoles R^1 = Et ; $R^2 = R^3$

R^2 & R^3	Activity * (kg/ha)	Log P	Es
Et	$\frac{1}{4} - \frac{1}{8}$	0.4	-0.21
Pr	1/16 - 1/32	1.4	-0.79
Pr^i	$\frac{1}{2} - \frac{1}{8}$	1.14	-1.01
Bu^i	$\frac{1}{2}$	2.14	-1.93
Bu^s	8	2.14	-2.33

* Rate required to control Echinochloa crus-galli and Digitaria sanguinalis in glasshouse tests.

Examination of the log P values shows no clear correlation between this parameter and activity. For instance the isobutyl substitution corresponds to a log P value of 2.14 which is identical to that for the sec-butyl substitution and yet there is a marked difference in their relative activities. Similarly when the Es values are examined activities when $R^2 = R^3$ = Ethyl and isopropyl are very similar and yet the Es values are -0.21 and -1.01 respectively.

When $R^2 \neq R^3$ (Table 2), a generally higher level of activity is apparent, particularly when R^1 = Pr. The sec-butyl group again tends to reduce activity, but activity is maintained with all other substituents, up to C_5.

TABLE 2

Effects of Structural Changes on Physico-Chemical Parameters and Activity of Selected Triazoles: R^1 = Pr ; R^2 = Et

R^3	Activity * (kg/ha)	Log P	Es
Pr	1/16	1.4	-0.79
Pr^i	1/32	1.27	-0.90
Bu	1/16	1.90	-0.82
Bu^i	1/32	1.77	-1.36
Bu^s	1 - ½	1.77	-1.56
n-Pent	1/8 - 1/16	2.40	-0.88**

* Rate required to control Echinochloa-crus galli and Digitaria sanguinalis in glasshouse tests.

** Estimated.

Once again no clear correlation exists between log P values and activity as shown by R^3 = isobutyl or secondary butyl. These substitutions also possess similar Es values and yet have markedly different levels of activity.

b) Substitution at the sulphur atom

When R^2 = R^3 (Table 3), activity is optimised at R^1 = Pr^n, Bu^n, Bu^s and Bu^i. As opposed to the carbamoyl substitution, sec-butyl groups are not deactivating, but isopropyl leads to decreased activity. Similarly, the longer-chain n-alkyl groups tend to reduce activity.

TABLE 3

Effects of Structural Changes on Physico-Chemical Parameters and Activity of Selected Triazoles: $R^2 = R^3 = Pr$

R^1	Activity* (kg/ha)	Log P	Es
Me	$\frac{1}{2} - \frac{1}{8}$	0.9	-0.72
Et	1/16 - 1/32	1.4	-0.79
Pr	1/32	1.9	-1.08
Pr^i	$\frac{1}{4}$	1.67	-1.19
Bu	1/16 - 1/32	2.4	-1.11
Bu^i	1/8 - 1/16	2.27	-1.65
Bu^s	1/16	2.27	-1.85
n-Pentyl	$\frac{1}{4}$	2.9	-1.17**

* Rate required to control *Echinochloa crus-galli* and *Digitaria sanguinalis* in glasshouse tests.

** Estimated.

In this case, once again, there is no relationship between log P values and activity. For instance when R^1 = ethyl or butyl the activities are identical but the log P values are markedly different. This is also true for Es values, when R^1 = iso-propyl or normal butyl the Es values are similar but activity is not.

When $R^2 \neq R^3$ (Table 4) activity is optimised at R^1 = iso-propyl, normal butyl and iso-butyl. Unlike the previous case (Table 3) iso-propyl is not deactivating. Again normal pentyl substitutions appear to limit the activity. The secondary-butyl substitution on the sulphur is once again shown not to be strongly deactivating as was the case with the carbamoyl substituents. (Tables 1 & 2).

TABLE 4

Effect of Structural Changes on Physico-Chemical Parameters and Activity of Selected Triazoles: R^2 = Et ; R^3 = Pr

R^1	Activity * (kg/ha)	Log P	Es
Et	1/4 - 1/16	0.90	-0.5
Pr	1/16	1.40	-0.79
Pr^i	1/16 - 1/32	1.27	-0.90
Bu	1/32	1.90	-0.82
Bu^i	1/32	1.77	-1.36
Bu^s	1/8	1.77	-1.56
n-Pentyl	1/1	2.40	-0.88**

* Rate required to control Echinochloa crus-galli and Digitaria sanguinalis in glasshouse tests.

** Estimated.

As in previous cases, there is no clear correlation between either log P or Es values and activity, when R^1 = isobutyl or secondary butyl log P = 1.77 however the activities differ four fold. Also the Es values for R^1 = isopropyl and normal pentyl are very similar being -0.90 and -0.88 respectively yet again there is a marked difference in their levels of activity.

c) Soil adsorption study

Table 5 shows the lack of correlation between glasshouse or field activity, degree of adsorption onto the soil, log P and Es values.

TABLE 5

Comparison of Field Activity, Log P Values, Es values & Soil Adsorption Characteristics

Compound	Relative Activity *	Percentage Unadsorbed	Log P	Es
1	a	89.2	1.40	-0.79
2	a	86.1	1.77	-0.93
3	a	79.5	2.14	-1.76
4	b	87.1	2.14	-2.13
5	b	83.6	1.40	-0.79
6	c	87.1	2.14	-2.34
7	c	94.7	1.51	-1.41
8	c	76.5	3.01	-3.19

* Under field conditions, a > b > c

DISCUSSION

Before entering into the discussion, certain general observations are pertinent. There are two main types of mathematical approach to structure-activity relationships the first of which (e.g. Hansch) invokes physicochemical parameters (Gould R.F. (ed) 1972) and the second (e.g. Free-Wilson) is solely concerned with structural features of the molecule (Craig, P.N. 1972). It seemed to us that physicochemical parameters of virtually all of the compounds of this group (such as ring electron density distribution and rates of hydrolysis) would be very similar to each other (we have confirmed this for the rates of hydrolysis of a selection of these compounds), and that therefore the best chance of being able to predict the structural features required for optimum activity lay in a 'structural' approach. We therefore undertook a 'Free-Wilson' analysis of a selection of our results, but no significant correlations whatsoever were found.

An examination of the structure of epronaz will show that the compound can occur as the 2-carbamoyl, 3-sulphonyl and 4-carbamoyl, 3-sulphonyl isomers as well as the preferred 1-carbamoyl, 3-sulphonyl form. Calculation of the log P & Es values for these compounds shows that all three isomers are identical in that log P = 1.40 and Es = -0.79. This leads us to propose that there is a basic steric requirement for the sulphonyl group to be attached to the three carbon and for the carbamoyl group to be attached to the one nitrogen. Once this fundamental configuration is achieved many compounds show activity. The range of log P values and Es values on active compounds presented in Tables 1 - 4 varies from 0.9 to 2.4 and from -0.5 to -1.85 respectively. By means of comparison these values have also been calculated for a group of inactive triazoles (Table 6). Clearly compound 4 has a log P value that falls within this range (1.97) and compound 5 has an Es value that also falls within the range (-1.26) but no compound possesses both.

Table 6

The Estimated Physico-Chemical Parameters of Inactive Carbamoyl Triazoles

R^1	R^2	R^3	Log P	Es
SO_2Et	Me	Me	-0.60	-0.07
Cl	Me	Me	0.47	+0.27
SO_2Bu^t	Bu^t	Bu^t	3.44	-4.62
Cl	Et	Pr	1.97	-0.16
SO_2Pr	n-Pent	n-Pent	3.90*	-1.26*

*Estimated.

We can, therefore, extend our hypothesis. It is likely that the compounds are active by virtue of their carbamoylating activity. That is to say the compounds mode of action is likely to be by attack on a nucleophile resulting in the decarbamoylation of the herbicide. If this hypothesis is true then it is probable that substitutions on the 3-sulphonyl group are unlikely to produce such large changes in activity as are substitutions on the carbamoyl group. It is also probable that the attachment of a methyl group to the α-carbon adjacent to the carbamoyl nitrogen (as in the case of sec-butyl) would increase steric hindrance more than the attachment of a methyl group to the β-carbon (as in the case of iso-butyl). These facts are borne out by our data.

Clearly factors such as log P and E_s are important if the compounds are to reach the site of action in the target organism. Partition coefficient and bulk must clearly play a role in terms of rate of uptake, movement and detoxification of a compound but these can only be important if the basic steric requirements for activity are met. Once this is done both are important; Log P and Es for uptake, translocation and accummulation at the site of action and Es for rate of hydrolysis within the plant. If the log P value falls outside a certain range (in our case

0.5 to 2.40) the compounds activity may be limited by its rate of uptake, partitioning either too much into the aqueous or too much into the lipophilic phase. If the Es value falls outside certain ranges (in our case -0.5 to -1.85) the bulk may preclude movement or the rate of hydrolysis may be either too slow or too rapid for the compounds to be effective.

The general conclusion is that it is too simplistic to consider only the partition coefficient or the bulk of substituents in terms of a compound's _in vivo_ activity. Factors that determine activity are complex and interacting and _in all_ cases fall with a range of values each of which modifies biological activity independently but each of which is dependent upon many other factors.

Acknowledgements

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A PLANNED APPROACH TO WILD OAT AND GRASS WEED CONTROL, INTEGRATING HERBICIDES WITH CULTURAL METHODS ON A LARGE CEREAL AND GRASS FARM

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Situated in Gloucestershire, at Eastleach near Cirencester, the farm covers an area of 995 hectares (2,360 acres). The land is mainly Cotswold Brash, which is a very thin soil with a depth of about 10 to 15 cm (4" to 6") but we also have 100 hectares (250 acres) of heavy land, of Evesham series clay. The height of the farm runs from 100m to 500m (350' to 550'). The average rainfall for the last ten years has been 809.2 mm but varies considerably from year to year, with a consequent impact on yields (see Table).

We grow 590 hectares (1460 acres) of cereals: of this 300 hectares (740 acres) are winter barley, 185 hectares (457 acres) winter wheat, 15 hectares (37 acres) winter oats, giving a total of 500 hectares (1235 acres) winter corn. There are 90 hectares (222 acres) of spring barley, 12 hectares (30 acres) of maize, 18 hectares (45 acres) of kale and 140 (346 acres) of leys. These consist of 92 hectares (226 acres) one and two year leys for silage and 43 hectares (120 acres) of one year ley for the sheep. There are also 87 hectares (216 acres) of permanent pasture and 87 hectares (217 acres) of rough grazing. Catch cropping, ie turnips and rape, sown after winter corn for the sheep in the autumn, amount to 45 hectares (110 acres).

Seven hundred and fifty cattle are reared for beef production. These are bought as calves at a few days old, are run on the pastures during the summer and are finished on silage at 18 to 20 months. They consist of Hereford cross and Friesian steers. Poll Hereford cattle have been bred since 1956, stock being imported from New Zealand, Australia, Canada and the USA. A thousand ewes are kept and at lambing time we have about 1600 lambs. These are reared for fat lamb production on an intensive grazing system. There are also a hundred sows for producing store pigs, selling at around 22 kilos (50 lbs) each.

Twelve years ago the weeds on this farm were bad, with a lot of couch, wild oats, some black grass and with the usual mixture of broadleaved weeds. Also, some of our neighbours had heavy infestations of wild oats.

We decided to study the whole farm thoroughly with a view to planning the control of weeds. If, as we were told, most acres of land have at least ten million weed seeds and in some cases this could go up to a hundred million, was there any way of controlling this? We decided that direct drilling was possibly the answer. Why turn over tons of soil and continually bring fresh weed seeds to the surface when only a working depth of about 4cm (1½") is wanted? But could we make this work and what would happen to the drainage?

Our first effort was a failure. We direct drilled wheat during November in the very wet season of 1968. The slots in the soil were such that the wheat died from waterlogging and slug attack and the result was a lot more couch!

Having failed at the first attempt we re-planned our weed control and cultivations policy and based it on the following:

1. Stopping ploughing and cultivating.

2. Extra spraying with herbicides, with the aim of killing any green, non crop growth.

3. Growing competitive crops to smother out weeds.

4. Intensively grazing and cutting leys for silage to prevent any shedding of seed by wild oats. Intensive grazing by sheep has also had a very beneficial effect in reducing couch (Agropyron) infestations.

5. Burning stubbles to destroy or break dormancy of wild oat and blackgrass seeds and check couch growth.

These five principles have been used over the last seven years and the whole farm has benefitted. The plough is still being used, and I suppose there will always be a need for it, to bury manure and plough in some leys before wheat, but instead of 100% ploughing, only 10% of the arable acreage is ploughed each year now.

We also decided that we would select two fields for a long run of direct drilling. One was thin brash land, and the other heavy Evesham series clay, both being 16 hectares (40 acres) in size. They have been direct drilled since. The heavy field is called Rough Ground; it had not been ploughed for over 100 years, not even during the war, when almost any piece of ground was cropped in the drive to produce more food, as it was not considered worthwhile. There were waterlogged areas, rushes in some parts and it was a very poor pasture. Ten years ago we ploughed it and planted wheat, this was repeated the next year. Areas still laid wet and yields were poor. The third year we direct drilled oats and since then we have grown wheat by direct drilling each year. With the field now in its eighth direct drilled crop the yields have increased and there are no wet patches. Spraying for broadleaved weeds is now confined to the headlands; wild oats and couch have disappeared and there has been no evidence of any build-up of blackgrass or other annual grass weeds. The organic count is 6.5% at the lowest time of year, and the soil colour has turned to dark brown. This year, there was not a crack to be seen despite the very dry summer whereas comparable fields not direct drilled cracked badly. Similar results have been seen on the lighter field which we treated in the same way.

Our diesel usage has gone down, we use less tractor power and have not needed to invest large sums in big tractors or heavy cultivation equipment. We have a lot more time for dealing with weeds and, of course, there is a reduction in the hours that our labour force have to work. I only wish that we had treated the whole farm in the same way. This year 500 hectares (1,235 acres) of winter corn have been sown, nearly all direct drilled, one third of which is being grown on contract for seed production. How has this happened? We found that by ploughing we destroyed over half of the worms and also damaged a lot of the soil bacteria. If these are left alone they appear to turn the soil over every two to three years and thereby improve the drainage.

With regard to cropping programmes, we like to grow as much winter corn as possible. The area has doubled over the last few years. Crops of wheat follow leys on the heavy ground, then two years winter barley before going back into wheat. How long we can carry this on for without trouble, we are not certain, but having grown ten years of continuous winter cereals on the heavy clay, the last seven of them direct drilled winter wheat, without building up any of the weed or soil problems predicted in some quarters, continuation looks more than a probability, if we do not run into disease problems. On the lighter land we start with a one or two year grass ley and then go into a long run of winter barley. This is yielding very well and, because of its smothering abilities, helps to keep weed problems under control.

After harvest is a very important time - there are 6 to 8 weeks in which the weeds are completely at our mercy! We use 'Gramoxone' (paraquat + wetter) in small doses to suppress grass weeds and larger amounts to clear up weed regrowth just before drilling, and also to kill grass leys before ploughing or direct drilling. This has, I am sure, been a key factor in preventing the establishment of annual grass weed infestations.

Burning is very important. It destroys the crop residue trash and helps to clean the surface of the soil. It kills some of the weed seed, breaks dormancy of more, and reduces disease risks. It also creates a very friable soil surface for direct drilling. The ash, according to some papers, is worth about £20 to £25 per hectare (£8 to £10 an acre).

Wild oats have been greatly reduced. Of course, by not ploughing or cultivating, the seed remains buried where it loses viability under the ground. After burning, seeds either grow and can be killed with 'Gramoxone' or are left on the surface and often lose their capacity to germinate. One of the problems with wild oats is to know when a field is clear of them. Where they now occur, we usually spray in the spring. 'Barnon' (flamprop-isopropyl) and 'Avenge' (difenzoquat) are used to control the wild oats in spring barley, 'Suffix' (benzoylprop-ethyl) in winter wheat, but difenzoquat scorched the barleys very badly this year and owing to the drought, they did not in some cases recover properly. There is still a need for safer and more effective wild oat herbicides. The problem we have to deal with now is that of patches of wild oats which may crop up without warning in fields we had thought were clean. We would very much like a herbicide which could be applied at a late stage to these oats without harming the crop. This could be applied through a hand held ULV sprayer perhaps. Hand roguing, either by pulling out the oats or by means of a chemically impregnated glove, is no longer a satisfactory solution to this problem, and the high cost of wild oat herbicides makes it uneconomic to spray whole fields to kill the odd patch of weed. Leys either for intensive sheep stocked at 20 ewes and 30 lambs per hectare or for silage are very helpful. Headlands must be watched for wild oats and sprayed by hand if necessary to prevent the oats shedding seed. The sheep wire is erected as close as possible to the outside of the field so that the sheep can graze any wild oats that are growing there. One of the ways wild oats come into a field is through birds and a close watch must be kept round trees and covers, etc. and barrier spraying carried out on these areas wherever oats show themselves in crops.

The way we control couch (A. repens) is by always keeping on top of it, never letting it grow away after harvest. The straw must be baled as soon as possible. If necessary, we then spray with 'Gramoxone', followed by a good burn. The couch is kept suppressed with small doses of paraquat - 1 pint (300 gms/ha + wetter) and then followed with a good smothering crop, preferably winter barley or winter oats. Leys are grazed intensively by sheep and the constant close grazing, followed by 5.6 litres per hectare (4 pints per acre) of 'Gramoxone' in the autumn before drilling, have worked wonders. A small amount of glyphosate has been used on the very worst areas but couch is not much of a problem now.

Blackgrass (Alopecurus mysuroides) has been controlled by constant watch on fields where this weed has occurred. Preventative action by treatment with chlortoluron or isoproturon pre-emergence of the wheat has been effective. Metoxuron is used on any blackgrass escaping this treatment. It has now almost ceased to be a problem, but of course, we must not become complacent about this! Care is taken to see that seeds are not spread from infected fields by dirty combine harvesters to clean fields.

Broadleaved weeds are now becoming very much less of a problem. In many of the fields that have been direct drilled for several years, we only have to spray the headlands with hormone type weedkillers in the spring.

We now keep detailed records and a plan of all fields as to pinpoint where problems may occur. These include cultural treatment, ie direct drilled or ploughed, dates and quantities of Nitrogen top dressings etc, kinds of sprays and mixtures of sprays, dates and who carries this out, yields, etc. Just before harvest all fields are inspected, and a note of the weed pattern is made. Also our combine harvester drivers are asked to keep a record of areas of poor crop or weed infestations. Clean seed corn is very important.

We buy in only first generation multipication stock seed, and take great care to grow it only on land absolutely clean of wild oats. Clean combine harvesters are used to harvest this and we keep a cleaner and grain dryer exclusively for use with seed corn, both that grown on contract and for the seed which we grow for our own use.

Some crops of cereals are better at smothering weeds than others. Winter barley is by far the best. Oats and wheat are not quite as good, especially some of the shorter strawed varieties. By direct drilling we get an even drilling depth of sowing and this helps with a quick germination and even establishment. Spraying with 'Gramoxone' just before drilling helps to get right on top of the weeds, and prevent any build up of annual grass.

Although we establish 100 hectares (250 acres) of grass ley each year, none of this is undersown. We have been direct drilling all our grass for six years and find it the most effective method of establishment. The drilling takes place as soon as possible after the corn has been cut. Sowing after harvest gives us another chance to get at the weeds and to select any field which we feel would benefit from extra weed control. Not having to worry about the cereals lodging, proper manuring can be given to enable a full crop of corn to be taken, together with the smothering effect on the weed population. Also by not undersowing, we can take the choice of collecting whatever straw is wanted, not having to wait for under sown fields to be harvested late in the season. Usually the early barley straws have the best feeding value. Quite often there is a break between winter barley and the rest of the harvest and it is a very useful time to clear straw bales and get at some of the weeds. On our light land we do not plough leys. Direct drilling has given us better cereal yields, together with the lessening of the weed seed population, being left undisturbed under the soil. On the heavy land, we are ploughing some grass before sowing wheat, but each year this gets less and less and I do not think it will be long before we stop ploughing altogether.

It is most important to have clean straw. Any straw that is of at all doubtful cleanliness with regard to wild oats or other grass weed seeds we feed out on permanent pastures and then if anything does germinate this is soon eradicated by the cattle or sheep grazing it. We try to keep our combines free from contamination by weed seeds. I wish we could find a smoke cartridge which when burnt while the combine is covered during the night, would destroy all weed seed. This would be an excellent move to help clean up this sort of contamination.

We try to have as much spraying power as possible. Flood jets on the end of the spray boom are a must so that we can get into the headlands to kill the weeds which are under walls or in the hedges. We have standardised working widths to 12 metres (40 feet) and all our equipment, including fertilizer spreaders fit into this width. This I feel will help us to work more accurately, although at present we have not gone over to tramlines as our three drills are of different sizes. Because of the good soil structure we can spray at most times of the year without undue damage. Disease problems seem to have lowered, but I do think we may have to watch out for eyespot in a long run of wheat. So far this has not occurred.

The main source of weed infection on the farm seems to be weeds spreading in from under trees; this is caused by birds or in some cases by contaminated combines. I went to a neighbour's farm the other day and he had moved a combine from a farm that had blackgrass on it to a previously uninfected field. The following spring there was a heavy black grass infestation round the edge of the field and it was not until one went to where the combine had been round three or four times that the blackgrass began to tail off. On fields which are nearly clear of weeds, we have adopted a policy of spraying round three times with an appropriate herbicide using a 12 metre boom. This gives us a total of 36 metres of spraying. We normally use three 4 metre combines and so, if each combine goes round the field three times, this would take up about 36 metres of cut and by that time we think that possibly most of the weeds will have come out of the combine. Before spraying time, we try to get in an expert to give us the best advice on how to treat the problems which are arising at that time.

After harvest we grow 45 hectares of forage brassica crops, a mixture of turnips and rape. This has a great effect on suppressing weeds. Wild oats, annual grass and volunteer cereals are controlled by a spray programme of a 'Gramoxone' spray before drilling and 3 kg/ha of dalapon applied selectively as soon as the crop has two true leaves. We have found this treatment very effective. We have not had a bare fallow for 10 years.

Weed control on the main crop brassica acreage is carried out with 'Cobex' (dinitramine), which is incorporated in the soil before the seed is drilled. Any wild oats escaping this are treated with dalapon applied post emergence to the crop. Permanent pastures are something which have to be watched, especially for blowing seed, and we try as much as possible to suppress these. We re-seed somewhere in the region of about 15 hectares (40 acres) a year by direct drilling and three months later spray out any weeds that have occurred with a hormone weedkiller - usually a 2,4,DB proprietary mixture. This has been of considerable value, as the stocking rate has been increased by two to three times from these old pastures.

Forage maize has been grown on 12 hectares for the last three years as an insurance against dry summers. Weed control here is carried out with atrazine, and this has proved satisfactory for the job in hand.

Conservation both in wild bird life and wild flowers is very important to us. We try to preserve the pheasants and partridges, and have a very good shoot. The weed programme, as it is at present, has had no detrimental effect on these, and in fact we have had only beneficial results from it. The partridge population has increased over the last six years since we changed our cultural policy, and we are able to hold more partridge shoots now than we were in the late sixties.

In some years slugs can be a pest with direct drilling. If these do become a problem, then mini slug pellets based on metaldehyde will clear them up, but care must be taken to use the right sort, as one type we used killed a lot of bird life. Last year we ran into a problem with frit fly. This was on leys which had been direct drilled and on some ploughed land, but was overcome by spraying with 'Blex' (pirimiphos-methyl) or 'Agrothion' 20 (fenitrothion).

One weed which seems to be standing out this year is Convolvulus. This seems to have established itself through the dry weather due to its deep rooting habit. Oat grass (Bromus sterilis) is becoming a slight problem on some headlands and is something we shall have to keep an eye on.

Volunteer crops can be a nuisance, but a light harrow put over the land after burning encourages germination of all the seed. These can then be sprayed off before drilling.

Of course, we still have our problems, but in spite of doubling our winter corn acreage and direct drilling most of it, our wild oats, couch, and blackgrass are getting less and in many fields have disappeared. Our yields have increased over the seven year period - on the two continuous direct drilled fields by 25%. The grain output from the farm as a whole has increased as a result of the switch from spring sown cereals to higher yielding winter crops, and we now also gain from being able to grow more premium seed crops on our wild oat clean land. The day to day running of the cereal side of the farm is simpler as we no longer have an enormous amount of ploughing and cultivations to carry out. Our system suits us and we intend to stick with it, developing it further as future conditions demand.

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TABLE 1 YIELDS OF WINTER & SPRING CORN/RAINFALL

Year	Winter Corn			Rainfall (mm)		Spring Corn		
	Hectares	Average Yield t/ha	Total Yield (tonnes)	Annual	Mar-June	Hectares	Average Yield t/ha	Total Yield (tonnes)
1970	347	4.16	1443	-	-	234	2.73	639
1971	446	4.19	1869	734	223	142	3.99	567
1972	480	4.37	2098	761	237	134	3.64	488
1973	481	4.47	2150	564	214	104	3.89	405
1974	483	4.42	2134	876	129	100	3.89	389
1975	431	4.23	1823	620	176	166	3.31	549
1976	445	4.47	1989	217	107	151	3.09	467

TABLE 2 WINTER DIRECT DRILLING AT MANOR FARM (hectares)

YEAR	DIRECT DRILLED	PLOUGHED	TOTAL
1970	34	350	384
1971	79	328	407
1972	125	323	448
1973	314	155	469
1974	331	142	473
1975	371	111	482
1976	519	27	546