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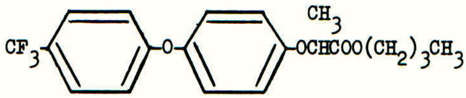
Page 30

Chemical structure should be:



Page 167

Bottom line should read:

to the same rate post-sowing-post-emergence.

Page 87

Table 1, column headed 'Winter Wheat' 'Maris Huntsman'

L.S.D. between timing means (5%) should read 0.356

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THE EIGHTH BAWDEN 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

HOW MUCH CROP PROTECTION CAN WE AFFORD IN THE 1980s?

by

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Switzerland

HOW MUCH CROP PROTECTION CAN WE AFFORD IN THE 1980s ?

T. W. Parton

The Bawden Memorial Lecture is given annually in memory of Sir Frederic Bawden, who was the first President of the British Crop Protection Council and for many years Director of Rothamsted Experimental Station. Sir Frederic's name is legendary and it is a great privilege for me to be given the opportunity and the responsibility of delivering the Eighth Bawden Lecture.

I understand, Mr President, that your Council forecast some time ago that the day would dawn when you would have a lecturer who knew Bawden little if at all. I regret to advise you that that moment has arrived. I did not have the privilege of knowing Sir Frederic and cannot claim to have benefited from the leadership and example which he showed to all who were associated with him. However, I will do my best to make a contribution to your Conference, recognizing, as I do, that I have a difficult task to follow my illustrious predecessors.

My own qualifications for the task are modest. This is my first Brighton Conference and I am ill-equiped to speak authoritatively on any of the natural sciences that have an impact on agriculture. However, I have been involved in the chemical industry all my working life and my responsibilities have required me to take a broad view of economic questions. It is particularly of the economics of crop protection that I want to speak. To the scientists in my audience I apologise for the absence of quantitative data - I realize the credibility risk that I run !

I am aware that I am speaking at the British Crop Protection Conference, but I believe that it is necessary to look at the question in its international context. So although I shall have regard to the British and European situation, I am sure that it is essential for us to think in international terms when answering the question "How much Crop Protection can we afford in the 1980s?". Moreover I am not unmindful of the fact that delegates from 47 countries attended the Conference last year and therefore my audience today is likely to be looking at this question from many different national standpoints. Furthermore, it is clear that the chemical industry supplying agriculture has for many reasons become international in its scope and it is from this background that I speak.

The title of my lecture is "How much Crop Protection can we afford in the 1980s?" and I want to begin by defining what I mean by crop protection. I know that this is the year of the weeds in Brighton, but I have the Council's permission, and indeed encouragement, to break with tradition and talk not only about weeds. I want to define crop protection as all those actions taken by a farmer to protect and improve his crop. I mean, of course, the various inputs with which he is involved, namely labour, natural resources - particularly water -, machinery, seeds, biologicals, chemicals, and finally, the professional advice or his own professional skills that he brings to bear on combining these inputs in an optimal way. Some of you may recognise in what I have said a description of good husbandry, others a description of integrated pest management. If this has happended it does not surprise me, because in my judgement both good husbandry and integrated pest management add up to the same thing - namely crop protection.

Having defined what I mean by crop protection, I would now like to turn to a second item in the title of my lecture, namely afford. What do we mean by "Can we afford?" In my judgement it means two things: "Have we the resources"and secondly, "Are there alternative ways of using these resources?". All of us involved with crop protection, whether as givers or receivers of goods and services, are faced with the problem of resources. All of us are concerned with the use of these resources in order to derive benefits. We all want to make resource allocations in order to optimize our benefits. And it is this cost/benefit analysis that I want to focus on when answering the question "How much Crop Protection can we afford in the 1980s?"

The last definition that I want to address myself to in my talk is the little word we. How much Crop Protection can we afford in the 1980s? I believe that we can only answer this question by identifying those who have an interest in crop protection and I have chosen to identify four groups that have such an interest.

Firstly, and foremostly, we have the farmer who is the engine room of the crop protection system. Or, using computer parlance, he is the black box who receives inputs and delivers outputs.

Secondly we have the consumer. The consumer is concerned with the outputs and clearly is a very interested party in this business of crop protection.

Thirdly, we have governments, which are involved in many ways in the total crop protection system.

Finally, there is the group which is concerned with the inputs to crop protection and here I propose, for the purpose of my lecture, to speak primarily about the chemical industry which, I recognize, is concerned with only one of the many inputs that are involved in crop protection.

Having defined what I mean by we, I would now like to take each of these segments in turn and examine the changing objectives.

Can we now look at the first of my segments - the farmer. What are his objectives in the 1980s?

Firstly, he has to look for increased yields from all his crops. He is required to do this because in the first place the demand for food to feed the increasing populations of the world will increase substantially. The last figures that I read suggest that the population will be 50% higher in the year 2000 than it is today - a powerful reason for increased yields or better crop protection, particularly in the developing countries, where there is usually a more direct and obvious like between the producer and consumer.

Secondly, the land available to agriculture will be reduced, partly because it is being diverted to other uses and partly because it is still being lost to agriculture owing to the effect of soil erosion, salination etc.

The farmer will also be looking for ways of reducing energy consumption. The energy which he expends on the farm will cost him more, and many of his inputs will be affected by the high cost of energy. He will be looking for ways of changing his input mix so as to reduce the impact of higher energy costs. In some cases he may well be faced with adding a fourth "F" to his outputs. In other words, he will not only be concerned with food, feed-stuffs and fibre but he may well be concerned also with raw materials for fuel. This is, of course, already a fact in a number of countries, particularly Brazil. I think we can look in the 80s for an increased tendency in this direction which will, of course, indirectly put greater pressure on the demany for yield improvement in crops used for food, feed-stuffs and fibre. This new dimension to the farmer's outputs will also pose new problems in crop protection.

With the move to urban areas continuing throughout the world, the farmer in the 1980s will also be concerned with a continuing change in the nature and amount of manpower available to him. Difficult as it is for some of us to accept, the attractions of urban living are great. Perhaps the speed with which this happens may change, but the trend of the 70s will continue, I believe into the 80s. The farmer will therefore be looking for ways of improving his utilization of labour in response to this enforced resource reduction.

He will also have to be adaptable to changing cultural practices. The speed with which these changes take place will vary but in the United Kingdom, for example, he is certainly going to be concerned with changes such as the move to winter-sown cereals.

In developed countries he is going to want to optimize the bewildering range of inputs by using the skilled professional advice that is available to him. However, in identifying these two examples we should be aware of the fact that most farmers throughout the world will not have available professional advice and advanced husbandry techniques, and they will still be looking for simple inputs in order to achieve their objectives.

The farmer, then, is looking for improved yields, better use of energy, improved labour utilisation, and a capacity to adapt, all of which he will want to achieve at minimum cost because one thing is clear: the 1980s are going to bring increasing pressure on prices, whether as a result of straight consumer pressure or as a result of Government action. Moreover, and above all, the farmer must have an adequate return for the capital and labour he employs.

Now what about the consumer - the body of people that includes all of us here today who are concerned with the output from the crop protection system ?

Firstly, there are those million extra consumers who appear on the scene every day or every week, depending upon which statistics you look at, and whose principal objective is to get enough to eat and thus survive. Although many do not recognise it, they are very much concerned with the same objective as the farmer, namely increased yields and a reduction in crop losses caused by inadequate protection.

The second consumer objective is cheaper food. The intensity of demand for it depends on the percentage of income that the particular consumer spends on food. The greater the percentage, the greater his or her demand for cheaper food.

Thirdly, the food, insofar as it is consumed directly from the farm, has to be aesthetically attractive. One may argue about the social merits of this consumer preference, but is a clearly established economic fact and, of course, the demand will vary according to the resources available to the consumer. The variety of food that has become available to the more fortunate consumer will also need to be maintained.

The last in the line of consumers' objectives that I have identified is that the products which are consumed must, of course, be produced under environmentally acceptable conditions. Yet again it does not take too much imaginiation to appreciate that this objective will vary according to the standpoint of the consumer, and particularly of his or her resources.

Summarising then, the consumer wants enough food, at an acceptable price and, in many cases, aesthetically attractive. He wants to at least maintain the variety he has come to expect and to have his food produced under increasingly environmentally acceptable conditions.

Government, too, have a resource problem. They have to look at the cost/benefit relationship when allocating what will be increasingly scarce resources. The fields in which Government action impinge on crop protection are basically education, including advisory services, research, and protection of the general public interest, i.e. legislative action. Governments are involved in both the direct use of resources and in action which involves a redirection of the use of resources by others.

The first field of Government involvement is education: the basic education of the farmer and what I suppose in industrial terms could be described as after sales service - keeping the farmer up-to-date with modern agricultural practice by the use of professional advisory services. I predict that the 1980s are going to bring increasing cost pressure on this areaof Government at a time when the complexities of crop protection will never have been greater. It seems to me vital, therefore, that the closest possible co-operation takes place between the educational and advisory units of Government and all others involved in supplying inputs to Agriculture in order to take full advantage of the available technical information and to avoid overlapping and wasteful use of scarce resources.

Because Government research, too, is unlikely to have unlimited resources in the 80s, it seems to me that these limited resources must be devoted to areas which are unlikely to be covered by the private sector. Examples, I suggest, lie in the fields of national specific problems, particularly where national security goals such as self-sufficiency in particular crops are involved. Research projects where the objectives would be either to increase the use of underutilised resources or to improve the efficiency with which limited national resources are used might be other examples of suitable Government sponsored research. In this context I think of better water management or alternative energy sources. It also seems to me that there would be few better ways for developed countries to offer development aid than by sponsoring research projects designed to solve the particular agricultural problems of the developing countries.

The third area of Government involvement in crop protection lies in legislative action. It is the area in which Government is not so much concerned with the allocation of its own resources as in imposing resource allocation on others. It is the area which calls for the greatest care to ensure that there is a proper cost/benefit study of the impact of Government action. Steps must be taken to ensure that the implications for the public at large are fully recognized whenever legislation affecting crop protection is introduced. Crop protection does effect everyone because everyone is a consumer and therefore a beneficiary. Firstly, anything that increases the cost of crop protection will, in the absence of a change in any other factor, reduce the output from agriculture because the marginal producer will cease to produce. The marginal producer is that producer whose input costs are only just balanced by his income. Thus any increase in his input costs will make his production uneconomic. One might argue that this may be corrected by a change in resource allocation by the consumer. In other words, if the consumer is prepared to devote more of his income to food, the marginal producer may be kept in business by an increase in income. This may be true in the case of a consumer who has enough to eat, but it will not be true of the consumer who already allocates the maximum of his/her resources to food. It is therefore less of a problem for British and European Governments than for developing countries. Yet even developed countries should be aware that it is the marginal consumer who will be affected by the increased production. The marginal consumer is that consumer who can only just afford his consumption at today's price levels and whose consumption will drop with any given increase in costs. In an ideal world the legislation of each country should be tailored to the different cost/benefit considerations of that country. However, many developing countries are forced to accept the legislative requirements of more developed countries, and this often results in an imbalance between their costs and benefits.

One way in which Governments are being urged to reduce the cost of crop protection is by harmonising their requirements for new product registration. This is clearly very desirable but I would add a few words of caution. I suggest that those sitting on harmonisation committees do not try to do everything at once. I believe that a regional approach is desirable initially and room should be left for individual initiative to improve the system on a continuous basis. It is also essential that each country should have the opportunity to reflect its own particular cost/benefit analysis. Having said that, it is clearly beneficial to avoid expensive individual country requirements where nothing is added to the benefit, namely, consumer protection.

I believe that is is unnecessary to say it to this audience, but there are still people about who are afflicted with the 'no risk' syndrome. Even though all benefits involve some risk and some cost, Governments are still bombarded by special interest groups who would have you believe that benefits can be obtained without cost. There are no free lunches - as I discovered when I became aware that I would be your Council's guest for lunch today after I had spoken to you this morning and not before.

Patent protection is another area of Governmental concern which is intended to provide a climate for increased research. The system depends for its success on persuading inventors to share their knowledge with others on the understanding that they will enjoy freedom from direct competition (and I emphasize direct competition because disclosure of the invention already ensures plenty of indirect competition) during the life of the patent. The useful patent life for chemical substances used in crop protection in many countries has been substantially reduced because of the Government requirements which must be satisfied to prove the safety of the compound. This effective reduction in the patent life will reduce the amount of research being carried out in the private sector because it is becoming uneconomic to pursue research goals in marginal areas. I believe that there is a clear case for reviewing patent law under these new circumstances and perhaps dating the patent life from the moment when registration occurs.

As I said earlier, the fourth group concerned with crop protection is that group concerned with inputs to the farmer and I have chosen to look at the chemical industry in particular as representative of this group. What are the resource allocation problems that the industry is facing in the 80s?

Firstly, the recurring theme in all the other contributors to crop protection, that of cost, is going to dominate the scene for the chemical supplier as well. The industry is clearly going to face increased costs from its principal raw material - oil. The demand for more information, not only to support new product registrations but also for existing products, will clearly increase costs, too. This will occur not only because of the cost of the information itself but also because there will be a demand for more specific solutions to crop protection problems, i.e. less broad spectrum products - particularly insecticides.

This increase in costs facing the chemical industry will occur at the same time as the farmer is looking for both reduced crop protection costs and increased yields. What does this mean for the chemical industry? In the first instance it means that the ever-increasing demand for improved productivity is by using economies of scale. The international nature of our industry illustrates this development, which will undoubtedly intensify. A further development arising from the high cost of research, development and registration means that only high value crops can be the prime target for industrial research. That does not mean that products will not be adapted to meet the needs of smaller crops, but these applications will be by-products from the main research objective. It will be obvious, therefore, that one of the consequences of high registration costs and the increasingly high technical standards required will be a gradual narrowing of the range of crops that can afford modern crop protection. I predict that the high value crops will get an increasing share of the research effort as the normal economic laws operate.

Increased energy costs faced by the farmer will undoubtedly have an effect on the direction of our research in the future. We will be looking for products that have a greater or longer activity per unit of active ingredient and thus reduce the treatment cost of the compound, and particularly the cost of applying it. So we will be looking for new formulations and application techniques to use these new compounds. The higher energy costs will lead, as they are already doing, to changing agricultural practices such as minimum tillage, double cropping, etc., and this will call for the development of new products to respond to the problems stemming from these changing practices.

We must recognize that one of the consequences of the demand for reduced costs will be that the farmer must look for the optimal use of the inputs which give him crop protection. The farmer of the 80s, although to a varying degree, is going to be better informed about these inputs and how to optimize them. He is going to require more information from the industry as to how chemical solutions fit into the total system of crop protection. We see this as a natural development and one which will probably include even more information on the inter-relationship of different compounds, including those of different producers.

I have confined myself to the chemical inputs to crop protection, but it should of course be pointed out that none of the inputs can be looked at in isolation. The interplay with seed developments and the use of biologicals will be obvious to you and must be of concern to those of us in the chemical industry who have the task of helping to ensure that the maximum crop protection is available to the farmer.

These, then, are some of the problems which we - meaning farmers, consumers, Government and industry - have to wrestle with in the 1980s if we are to afford the crop protection that we need. I hope that I have made it clear that we are interdependent and that we should all avoid the pursuit of narrow interest objectives which do not take account of the broader issue of crop protection which is of interest to us all. I recognize that in addressing the Brighton Conference, I am in danger of preaching to the converted, because The British Crop Protection Council is probably unique in numbering amongst its member bodies, representatives of all the groups of which I have spoken. I believe that the aims and objectives of the B.C.P.C. are precisely in harmony with what I have been saying, and I believe that we should continue to use the forum they provide and attempt to expand it even further beyond Britain in our efforts to ensure that we can afford the crop protection that we need in the 80s.

NEW CONCEPTS AND NEW COMPOUNDS IN WEED CONTROL

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Despite its title, Plenary Session 2 is dominated by new compounds although some relatively recent concepts are explored under the wing of new compounds.

From the papers, DPX 4189, fluazifop-butyl, NP55 and the new thiopyrimidines appear to offer significant additions to the already impressive armoury of herbicides. It is pleasantly surprising, in view of long-standing pessimism over the costs of discovery and development coupled with international recession, to see that new and exciting herbicides are still coming forward. Doubtless the best will find a ready market even in crops where competitors abound.

In September of last year the Royal Commission on Environmental Pollution gave its views on pesticides and conceding that continued use was essential to maintain food supplies nevertheless made a strong recommendation that it should be a declared policy to reduce pesticide usage to the minimum consistent with efficient food production. The argument that economics alone would ensure this was not wholly accepted. Whether the low rates of application of DPX 4189 can be interpreted as reducing herbicide usage is debatable for I suspect that the Royal Commission was thinking about spray-acres rather than Kg ha^{-1}.

Another recommendation from the Royal Commission was for a strong commitment to applying concepts of integrated control. Although this is an impressive label, weed control practices have always been integrated. What has been lacking has been a developed 'systems analysis' which allows a grower to choose the appropriate tactics within a clearly defined strategy. I for one would have been delighted to have seen even a theoretical treatment of this area in Session 2. I draw attention to an approach to this problem by Mortimer et al. which is presented in Plenary Session 5.

Any policy aimed at reducing herbicide usage is fraught with commercial problems for chemical industry however desirable such an aim may be for the environmentalist or the farmer. The costs of discovery, research and development have to be met by the sale of products and it cannot be attractive to a manufacturer to find that herbicide dose can be reduced four-fold by the use of additives or synergists (unless that manufacturer holds the patent for these) or to find that a particular method of application allows significant dose reduction. Yet the commercial pressures from the user are likely to be great. I raise this question not because additives are new but because the impact of basic research on them is likely to increase. The paper of Chow & Taylor touches on this aspect only indirectly but the wider implications merit serious discussion. The tightrope of adeouate returns for investment and the economics of protecting crop production is a delicate one.

Protectants (= safeners) represent an exciting if ill-understood development that may suddently extend to become commercially meaningful on a much larger scale. Here we are concerned with using chemicals that may or may not be biologically active. The prospect of rendering small-grain cereals resistant to a battery of older out-of-patent herbicides must be somewhat alarming. The report by Parker, Richardson and West indicates that 1,8-naphthalic anhydride (NA) will make wheat and barley more resistant to DPX 4189. Their immediate view is the opportunity to allow increases in the dose of the herbicide to control more resistant weeds; but the wider possibilities are also important.

Mixtures of known herbicides as opposed to mixtures of herbicides with surfactants or other additives merit some comment. A study of the list of approved products allows no claim that mixtures are new. What may be new is the apparent extent to which unapproved mixtures are created in the field. Data are difficult to find! However, it is one thing for a sprayer to become blocked through the precipitation of one of the products or for antagonism to occur, quite another if the mixture proves to be biologically active in some quite unpredictable way. I refer not to possible crop damage but rather to some unexpected deterioration of safety to man, domestic animals or wildlife. I stress that I refer to unofficial mixtures; side-effects are always possible, and the possibilities ought always to be examined. I hope it is not significant that the announcement of a new product includes a statement about the safety elements; the launching of a mixture does not always seem to follow the same path. Who could have predicted what ammonium thiocyanate does for aminotriazole or the extent to which ammonium sulphate activates many foliage-applied herbicides? Herbicides are biologically active chemicals and I am aware that the press, for reasons best known to itself, has launched and sustained a bitter attack on one herbicide in particular. Some sections of the press have an unacceptable range of new concepts for chemical weed control and they find support in some other quarters.

Fungicides and insecticides have been used on crops prior to harvest for many years and residues in crops have received careful attention. The use of glyphosate pre-harvest in wheat and barley (O'Keefe, Plenary Session 2) is an excellent example of the integration of herbicide usage into crop husbandry and is a novel development allowing a comparatively non-selective chemical to be used safely when the crop has become effectively resistant through maturity. If this type of development is extended to other herbicides, the whole area of herbicide residues in foods will need to be carefully re-examined.

Nevertheless, the session is mainly devoted to new compounds (more herbicides are announced in the poster-session 3C). The five new thiopyrimidines are pre- and post-emergence herbicides with potential in cereals for the control of grasses and broad-leaved weeds, NP55 controls annual and perennial grass weeds in various dicotyledonous crops, fluazifop-butyl is a post-emergence herbicide for selective control of annual and perennial grass weeds primarily in broad-leaved crops and DPX 4189 is a very active herbicide against broad-leaved weeds with the temperate small-grain cereals being resistant.

Against the background of the success of the phenoxyacetics, the first British Weed Control Conference 27 years ago was excited by the announcement of the second soil-applied herbicide, CMU (monuron). Subsequently, the extension of chemical weed control into crops other than small-grained cereals depended heavily on residuals. Margins of selectivity were sometimes too slight and too often upset by the soil. At this weed control conference in 1980, the outstanding features must surely be the tendency to return to post-emergence applications and the overwhelming excitement of the margins of selectivity which are again being offered. Our understanding of the comparative biochemistry of plants owes a great debt to the crop protection industry.

Proceedings 1980 British Crop Protection Conference - Weeds

THE NECESSITY OF WEED CONTROL IN WINTER CEREALS IN SCHLESWIG-HOLSTEIN

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Summary The first part of the paper describes the cropping of winter cereals in Schleswig-Holstein together with supporting statistics. The main problems and some basic input-output relationships are examined.

The second part is concerned with the results of herbicide trials and field experience in Schleswig-Holstein.

The third part looks at the economic aspects of weed control. Apart from theoretical considerations, some cost-yield relationships arising from trial and field results are described. The risk arising from no, or poor, weed control measures in intensive cereal growing can be described but not quantified exactly. Also touched upon is the problematic nature of weed control when using a damage treshhold. The papers resume is a consideration of the likely response of farmers to the current rise in costs, with finally an assertion that under Schleswig-Holstein conditions the use of herbicides is obligatory.

INTRODUCTION

As in other regions the current production of winter cereals in Schleswig-Holstein is very clearly different from the old husbandry methods. Getting high cereal yields has become an attempt to exhaust as far as possible the yield capacity of the plant, using all the possibilities which science offers. This implies, in most cases, employing all production measures up to the economically reasonable limit, in order to maximise yield. As a result of this philosophy, and the naturally fertile conditions, yields of 10 tonne or more of winter wheat are often reached in Schleswig-Holstein. The above remarks apply to winter barley also, although the yields on good farms are not as high as wheat.

Cropping of winter cereals in Schleswig-Holstein

The Federal State of Schleswig-Holstein presents, as can be seen from diagram 1, an enclosed entity bounded by the Danish border, the North and Baltic Seas and the Elbe. The geographical division into marshland, "Geest" (infertile, sandy heathland) and the eastern hilly country broadly characterizes the agricultural land use as well as the major weed problems.

In the areas of marshland, the North Sea coast region, where winter wheat is grown, blackgrass (Alopecurus myosuroides) is a serious competitor, often reaching some thousands of ears per m^2. As a result of the early drilling, about beginning of September, the very heavy adsorptive soil and relatively high autumn and winter rainfall, blackgrass quickly develops into the major factor affecting crop yield.

The dicotyledonous weeds do not normally present a difficult problem. The most frequent are mayweeds (Tripleurospernum and other spp), chickweed (Stellaria media), cleavers (Gallium aparine) and speedwells (Veronica spp). Normally there is a treatment with a 'hormone' weedkiller in the spring, after the application of a residual herbicide in the autumn.

Crops on the geographically oldest land of the backbone of Schleswig-Holstein, the "Geest" plain, are, apart from grass, winter rye and spring oats and barley, mainly because of the relative low fertility of the soil due to the high sand content. The major weed in winter rye is silky bent (Apera spica-venti), accompanied by a multitude of dicots such as Viola spp, chickweed, poppies (Papaver spp), cornflower (Centaurea cyanus), knotgrass (Polygonum aviculare), Veronica spp and others. This mixed weed population results from the low intensity of both cereals and control measures; nearly all "Geest" farms depend upon stock for their existence.

In the eastern hilly country winter cereals and rape predominate. The soil conditions, originally determined in the Ice Age, vary considerably as does the corresponding weed flora. Frequently one finds in the more or less heavy dicot population silky bent and annual meadow grass (Poa annua) and, on the eastern side in the heavy soils, also blackgrass. It is therefore very difficult to classify the weed flora in this area as one can do for both the other areas, marshland and "Geest". The choice of herbicides is influenced much more by the type of grass infestation than the presence of dicots. Winter wheat husbandry reaches a very high level of intensity particularly in the East Holstein area with its fertile high-yielding soil and preponderance of large farms.

As can be seen in figure 2, winter wheat and winter barley acreage is still increasing in Schleswig-Holstein. The increase in winter wheat comes above all from the ploughing-up of grassland in the marsh areas. Growing of winter barley despite the fact that it overwintered very badly in 1979, is spreading, particularly in the "Geest", because its yield and reliability are better than those of rye or spring cereals. Altogether there are about 340,000 ha down to winter cereals in Schleswig-Holstein.

Crop rotation is an important point when considering the weed problem. The proportion of winter crops in the rotation, as can be calculated from table 1, is very characteristic of the geographic areas. In the marshland, currently mono-culture of winter wheat is practised on about 60% of total arable land, whereas winter barley only accounts for about 10%. Wheat yields here are on average significantly higher than in the other areas; naturally this intensiv wheat cropping encourages heavy blackgrass infestation.

The cropping pattern of the "Geest" demonstrates the infertility of the soil. Mostly rye is cultivated, but not intensively.

In the hilly eastern region there is about 75% winter cropping whereby the proportion of barley and rape are about equal due to the direct rotational relationship. A rotation often found is winter barley, winter rape, winter wheat. Also here the intensive nature of the cropping pattern and the corresponding husbandry encourages the increase of grass weeds and, in turn, the introduction of residual herbicides brings with it a selection of dicot weeds including cleavers and *Veronica* spp - just as in the marshland.

Costs and Returns of Winter Wheat Production

Table 2 gives an insight into the costs of wheat growing from 1975 to 1978. The data comes from 30 farms in the hilly eastern region with a total recorded area of about 2,500 ha per year. Alongside the figures for the good year 1978 are shown the mean figures for the period 1975 - 1978. The yield figures indicate the quality of the farms whereas the variable costs and gross returns (one tonne grain = £ 120) show the profitability. The standard deviations demonstrate the variance in costs - which is greatest with herbicides. These account, on average, for about one third of the total crop protection costs, but only around 7.5% of the total variable costs. This order of magnitude may be most useful as a reference value.

As a result of further more intensive use of fungicides and N-fertilizer, plus rising prices, the variable costs have risen since 1978 - as shown in table 3. In 1979 and 1980 they could be in the region of £ 280 - £ 300/ha for winter wheat and about £ 45 lower for winter barley. Again herbicides form about 7 - 10% of the total. Currently the largest price rises are in machinery and fertilizers - pesticides are with a wide margin only in third place.

Results of herbicide trials in Schleswig-Holstein

The weeds found in early sown winter wheat fields result from a decade or more of a process of selection and they resemble cereals in respect of the factors affecting germination and growth. As mentioned earlier we are concerned with such competitors as blackgrass, silky bent, chickweed, cleavers, mayweeds, speedwells and dead-nettles (*Lamium* spp). Their competitiveness is however so great that they rapidly outgrow the cereal once it has germinated and often in autumn cover the entire ground. The early development of the cereal plant including root development, tillering and ear length can all be influenced irrespective of weed density and spectrum or length of the competitive phase, and once this has happened compensation by fertilizer usage or other measures is hardly possible. Early removal of weed competition is therefore regarded by most experts (Garburg 1979, Reschke 1980, Hornig et al 1979 etc.) as a basic requirement of intensive cereal growing.

Modern cereal growing techniques have led to an ever shortening period between harvest and re-sowing. Currently, in wheat monoculture on the marshland, there are 2 to 3 weeks available for soil cultivation and sowing. Minimal cultivation or direct-drilling is not common; the plough with subsequent seed-bed preparation remains standard. As a result there is little time in which weed seeds near the soil surface can germinate and be destroyed by subsequent soil cultivation - with significant consequences for weed control practice. In the hilly eastern region this is particularly true for winter barley - whereas winter wheat after rape or beet tend to be drilled later allowing more time for cultivation.

There is an immense number of trials testifying to the yield-enhancing potential of herbicides as reported by Elliott (1978) at the last conference, and to this can be added the knowledge obtained by farmers in their practical use of herbicides in intensive cereals growing. One representative example comes from F. Matthiesen, one of the largest, and, perhaps because of his yields, best known, wheat farmers in Schleswig-Holstein. He states that in the classical blackgrass areas of the marshland it was not until the introduction of highly effective grass residual herbicides, for example chlortoluron, that the conditions were met for the economic introduction of other production measures.

From Meyer et al (1978) it is clear that yield increase of 50 - 60% (with a yield of 6 to 7 tonne in untreated) are achievable given heavy infestations of blackgrass and early sowing of wheat. Such yield increases are not automatically achieved, and in the whole west coast area multiple and expensive applications of herbicides are obligatory for their realisation.

In tables 4 and 5 are quoted trial results from over many years (Hornig et al 1978), which enable an impression to be gained about the circumstances in the eastern hilly country. From these results one sees that in blackgrass infested areas lower yield increases were obtained in comparison to silky bent infestations. One reason for this might lie in the lower dicot infestation. Winter barley showed less yield benefit from post-emergence herbicide applications - particularly in spring - when compared to pre-emergence use, while wheat showed this tendency only with the silky bent and dicot spectrum. Given blackgrass and dicot infestations, autumn or spring treatments were equal in effect-perhaps due to a relatively low blackgrass infestation ($< 1{,}000$ ears/m^2), a high yield level (up to 9 tonne) and, in comparison to barley, a somewhat later sowing date. The trials quoted resulted in a yield increase of 10 to 25% in the course of the years and according to infestation of grass and dicots. This increase is of such magnitude that herbicide treatment is economically sound.

In comparison the yield increase resulting from control of dicots only-here in winter barley - is lower; and timing of the application had no influence. From these results it follows, as indeed with many others (Beer 1979, Niemann & Grigo 1980, Koch & Hess 1980, etc.) that the crop, drilling date, soil, potential yield level and weed infestation should influence choice of herbicide.

The timing of herbicide application in Schleswig-Holstein depends not only on the direct damage arising from weed competition but also on the prevailing climatic and soil conditions. In most cases it is not possible to have tractor entry into winter wheat or barley fields in the autumn after drilling or in the early spring. Where an infestation of grass weeds can be foreseen the application of a residual pre-emergence herbicide is recommended, and it should have also a relatively good efficiency against dicots. A further treatment in the spring is not normally necessary, unless the soil and climatic conditions over winter materally reduce the effectiveness of the residual herbicide. There is little emergence of grass weeds in the winter or spring, however dicots such as cleavers act differently and must be taken into account when planning the herbicide programme.

Farm Management decisions

In many trials it has been demonstrated that winter wheat and winter barley, in respect of both level and reliability of yield, are clearly superior to spring cereals. It is therefore unnecessary to discuss crop rotation in respect of current weed problems on economic grounds as long as there is no basic alteration in the cost/return ratio.

From the farm management viewpoint weed control must be undertaken when the resulting increase in yield is higher than the costs of the control measures. As there are no mathematical models describing relationship between herbicide use and yield increase for specific cases, it is necessary for the agricultural economist to limit himself to calculation of the cost/benefit ratio. Table 6 shows the crop protection costs involved in cereal growing and the benefit - the extra yield which must be obtained to cover the higher expenditure, (Langbehn 1980). The costs shown are for spring 1980 and are indicative of those likely to be met by the farmer. If one looks at only the herbicide and application costs, the yield increase needed to cover these will be £ 32 or 300 kg/ha cereals. As already shown in trials over many years, the yield increases resulting from control of grass and dicot weeds lay between 10% and 25%. The yield level must therefore sink below 3 tonne/ha in order to disqualify herbicide use (methabenzthiazuron + CMPP).

If the weeds were entirely dicotyledonous then the maximum expenditure of about £ 18 would need to be covered by a yield increase of about 160 kg/ha, eg 3% with a yield level of 5 tonne/ha. Proceeding on the assumption that in Schleswig-Holstein a maximum of £ 45 is spent on herbicides (in spring 1980) we find that to cover this cost a yield increase of 400 kg/ha must be achived, and that is exactly 5% with a yield level of 8 tonne/ha.

These figures clearly show that crop protection measures are above all meaningful where cereal growing is undertaken at a high level of intensity. Nevertheless the effect of the applied products is dependent upon many factors eg spectrum of action and crop tolerance, timing of use, rate of use, local conditions, cultivar, yield potential, crop density, fertilizer use etc. (Langbehn 1980, Reschke 1980).

Besides this cost/benefit relationship which from the economic viewpoint is important, there are a number of further factors which induce the Schleswig-Holstein farmers currently to undertake prophylactic weed control. For instance it has become apparent that the crop often tolerates pre-emergence herbicides best of all. This may be due to the nature of the active ingredient but may also arise from the interdependence of herbicide, plant, climatic conditions in post-emergence treatments, which must in part be undertaken in unfavourable weather conditions as well as on advanced stages of weed growth - combining the risk of ineffectiveness with phytotoxicty (frost, rain etc.). Evidence for this can be found in the winter barley trials referred to earlier. In addition, as mentioned earlier, application in late autumn or early spring, the favourable times for spraying, may not be possible because of wet soil or adverse weather.

Further there is always the risk in well fertilized crops of lodging, despite the use of growth regulators, and under certain conditions this may well be deliberately brought about. Cereals, in particular winter barley, should bend after reaching the ripe stage Fe 11.3 in order that the often dominant strong winds do not shake the grains out of the ears. If, however, there are some weeds such as chickweed or cleavers left as a result of poor, or lack of, herbicidal treatment, these weeds can, in lodged cereals, cause considerable difficulties at harvest, increased threshing losses, secondary growth or absolute loss. These risks of lodging exist almost every in Schleswig-Holstein because of the high summer rainfall and slow ripening. Elliott (1978) describes very spectacularly the connected problems, including increased harvesting and cleaning costs, lower prices for grain contaminated with weed seeds and refusal of seed certification. In addition there is the strong threat to lodging cereals from increased fungi attack. Winter barley is naturally more at risk than winter wheat.

Because the totality of conditions in Schleswig-Holstein leads it to be regarded as a region where weeds are always damaging, such well know writers as Garburg (1979), Koch & Hess (1980) and Reschke (1980) all come to the conclusion that weed control must be undertaken in almost every instance. At this point the problematic nature of weed control when using a damage threshold becomes clear. At the time of herbicide application there is just no possibility of estimating exactly the eventual possible damage, just as much as there is no possibility shorty before harvest of eliminating earlier mistakes in weed control. Profit and loss calculations may be drawn up either on the basis of single trials or as means from multiple trials - as in this paper - however, any attempt to give exact dimensions will fail today and in future, because models can only be computed with <u>known</u> factors and correlations.

CONCLUSION

Why are winter cereals so intensively farmed in Schleswig-Holstein? The answer to this question was and is still the realized profit. In many cases it appears that the usage of crop protection products and fertilizers has already reached an maximum. The farmers returns are nominally constant but are in reality sinking due to inflation at 5.5%, and thus the farmer must take action in one form or another if he is to maintain a steady income.

In such a complicated system as the intensive production of cereals there can be no consideration of which one product or application could be spared should costs increase further. In a system, in which inputs are interdependent, one cannot think of a single measure and its effect, but must have regard for all the reciprocal effects. This applies not only to farm management considerations but also to the technical aspects.

The reaction of the farmer to the situation as described above will probably lie in the attempt to refine crop husbandry techniques still further and to cut costs by both better farm management and further rationalization. At the moment there is absolutely no thoughts about de-intensifying cereal production and thus move back into the past. For herbicide usage all of this signifies optimisation of effect by choise of product, timing of application, application conditions etc. and by these means to aim for an increase in yield above and beyond the normal.

Acknowledgements

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References

ANONYM, (1980) Bodennutzung und Ernte in Schleswig-Holstein 1979. Statistische Berichte des Statistischen Landesamtes Schleswig-Holstein, C I/C II - j/79, 34-45.

BEER, E. (1979) Ermittlung der Bekämpfungsschwellen und wirtschaftlichen Schadensschwellen von monokotylen und dikotylen Unkräutern in Winterweizen und Wintergerste anhand von Daten aus der amtlichen Mittelprüfung. Dissertation Göttingen.

ELLIOT, J.G. (1978) The economic objectives of weed control in cereals. Proceedings 1978 British Crop Protection Conference-Weeds, 14, 829-839.

GARBURG, W. (1979) Ackerfuchsschwanz und Windhalm jetzt bekämpfen. DLG-Mitteilungen 1979, 978-980.

HORNIG, H. et al. (1979) Versuchsergebnisse Pflanzenschutz im Ackerbau. Amt für Land- und Wasserwirtschaft Lübeck, Abt. Pflanzenschutz, Bericht 1979.

JÜRGENSEN, M. (1980) Private communication.

KLISCHOWSKI, B. und BEYER, H. (1979) Wechselwirkungen zwischen Ackerfuchsschwanzbesatz, Ertrag und Wirkungsgrad von Bekämpfungen in Winterweizen. Gesunde Pflanzen, 31, 132-138.

KOCH, W. und HESS, M. (1980) Weeds in wheat. Wheat Documentation CIBA-GEIGY, 1980, 33-40.

LANGBEHN, C. (1980) Strategie im Pflanzenschutz. Bauernblatt für Schleswig-Holstein, 34, 1045-1047.

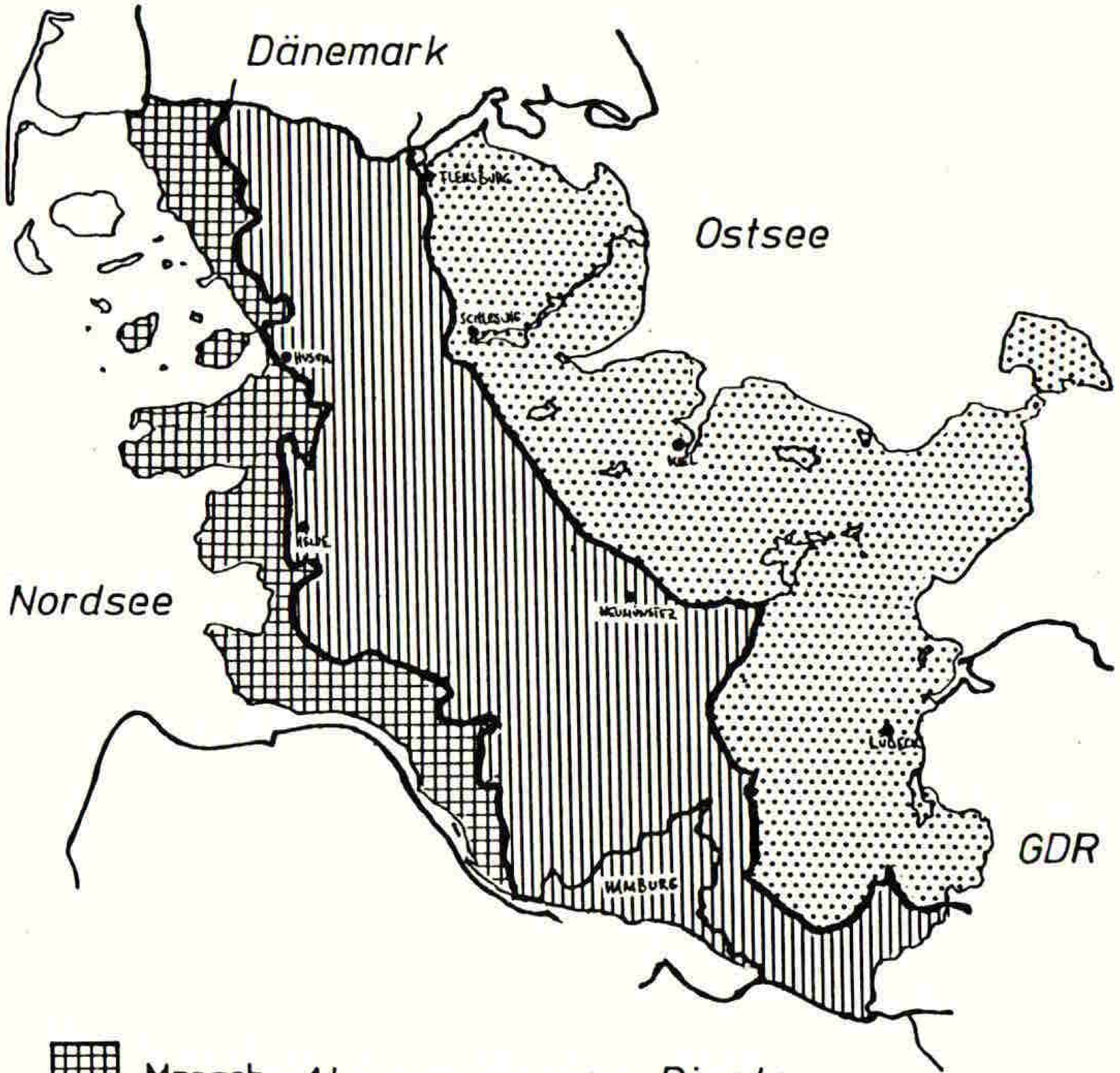
MEYER, J. et al. (1978) Aktuelles aus dem Pflanzenschutz. Versuchsergebnisse 1978 der Ämter für Land- und Wasserwirtschaft Heide und Husum, Abt. Pflanzenschutz.

NIEMANN, P. und GRIGO, E. (1980) Auswertung langjähriger Versuche zur Bekämpfung von mono- und dikotylen Unkräutern in Winterweizen und -gerste (1965-1979). Gesunde Pflanzen, 32, 213-218.

RESCHKE, M. (1980) Schwierigkeiten bei der Einführung der Unkrautbekämpfung nach dem Prinzip der Schadensschwelle. Phytomedizin, 10, Heft 4, 10-11.

Fig. 1

SCHLESWIG-HOLSTEIN



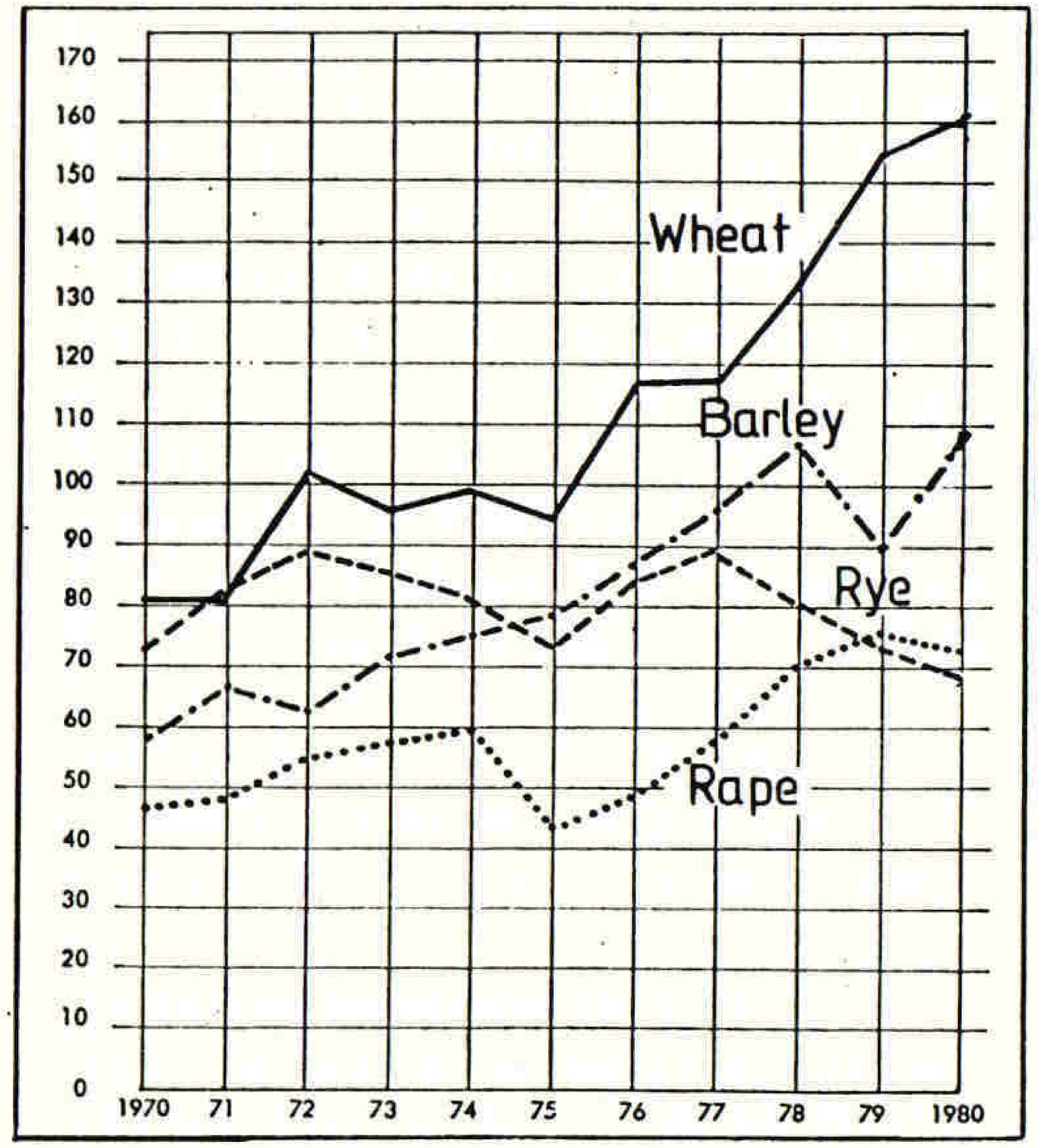
Marsch - *Alopecurus myos.* + *Dicots*

Geest - *Apera spica-venti* + *Dicots*

Hügelland - *Dicots* + *Monocotyledons*

Fig. 2

Winter Crops in Schleswig-Holstein



(in 1.000 ha)

Table 1

Crop area, yield and rotation share of winter crops in different regions of Schleswig-Holstein in 1979

		Crop area (ha)	Yield (t/ha)	Crop rotation share (%)
Marsch	total =	71,628 (arable land)		
wheat		42,236	6.50	59
barley		6,722	4.74	9
rye		996	4.02	1
rape		6,395	2.64	9
Geest	total =	203,125 (arable land)		
wheat		16,831	4.62	8
barley		14,446	3.96	7
rye		50,209	3.69	25
rape		4,708	2,52	2
Hügelland	total =	349,906 (arable land)		
wheat		96,006	5.81	27
barley		68,704	4.99	20
rye		23,916	4.35	7
rape		64,532	2.71	18

(Stat. Landesamt Schlesw.-Holst.1980)

Table 2

Yields (t/ha) and costs (£/ha) of winter wheat production of 30 farms

	1978 1)		1975-1978 2)	
	Mean	Standard Dev.	Mean	Standard Dev.
Yield	7.45	1.21	6.59	1.23
Crop protection	55.50	14.32	42.44	16.45
Herbicides	18.51	10.93	16.62	9.06
Fertilisers	88.09	29.83	90.81	30.90
Machinery equipment costs	45.72	11.72	43.38	13.58
Contructor costs	4.22	9.77	3.48	8.13
Variable costs of the crop	235.07	43.35	218.82	43.77
Crop output/ha	897.57	159.48	791.14	160.24

1) 95 Cases 2) 355 Cases 1£ = 4.33 DM (JÜRGENS 1980)

Table 3

Costs of winter wheat and winter barley production in Schleswig-Holstein (1980)

	winter wheat			winter barley		
	Quantity per ha	per unit	per ha	Quantity per ha	per unit	per ha
Seeds	220 kg	19.40	42.73	200 kg	19.40	38.80
Fertilisers			122.40			110.85
N	240 kg	0.30	71.59	200 kg	0.30	60.05
P_2O_5	120 kg	0.18	23.09	120 kg	0.18	23.09
K_2O	160 kg	0.09	13.86	160 kg	0.09	13.86
CaO	600 kg	0.02	13.86	600 kg	0.02	13.86
Crop Protection			76.21			66.97
Herbicides			28.87			28.87
Fungicides			32.33			23.09
Insecticides			3.46			---
Growth regulator			11.55			15.01
Machinery costs			57.74			51.96
Variable costs			300.23			267.90
Wages			92.38			92.38
Fixed charges			138.57			138.57
Production costs (without tenure)			531.18			498.85
Yield (expected)	8,0 t	115.47	923,79	7,0 t	103,93	727.48

(All figures are approximate values of well managed farms)

1 £ = 4.33 DM

Table 4

Control of mono- and dicotyledons in winter cereals

Mean results of long time trials

	Winter barley		Winter wheat	
	A. myosur. + dicots	A. sp.-venti + dicots	A. myosur. + dicots	A. sp.-venti + dicots
Yield untreated	100	100	100	100
Autumn Pre-em.				
chlortoluron	111	112	110	126
chlortoluron + hormone* (Spring)	111	122	111	117
trifluralin/linuron	113	122	105	115
pendimethalin	111	122	-	-
methabenzthiazuron	112	121	117	123
Autumn Post-em.				
chlortoluron	113	115	-	-
metoxuron	112	110	-	-
isoproturon + dinoseb acetate	-	107	-	-
Spring Post-em.				
chlortoluron	107	115	-	-
chlortoluron + hormone*	110	117	114	118
metoxuron	108	-	117	112
methabenzthiazuron	-	-	111	-
isoproturon/CMPP	-	-	113	116
isoproturon/bentazone/2,4-DP	-	112	114	108
isoproturon/ioxynil/CMPP	-	109	117	-

* CMPP or CMPP/2,4,5-T according to the weeds

(HORNIG et al. 1979)

Table 5

Weed control (dicotyledons) in winter barley

Mean results of some years

Untreated = 100%	Yield (rel.)	Number of testings
Autumn Pre-em.		
chlortoluron + hormone* (Spring)	105	4
trifluralin/linuron	105	5
pendimethalin	102	5
Autumn Post-em.		
dinoseb-acetate	104	5
ioxynil/CMPP	104	3
bromoxynil/ioxynil/CMPP	104	5
Spring Post-em.		
cyanazine/2,4-DP	107	2
bentazone/2,4-DP/2,4,5-T	103	5
ioxynil/CMPP	103	4
bromoxynil/ioxynil/CMPP	103	4
bromphenoxim/terbuthylazine/CMPP	104	2
dinoterb/CMPP	98	2
hormone*	100	5

* CMPP, CMPP/2,4,5-T or CMPP/2,4-D according to the weeds

(HORNIG et al. 1979)

Table 6

Crop protection treatments in winter wheat

Treatments	a.i.	Dose kg/l/ha	1) Price per unit	Produkt costs/ha	2) Treatment costs/ha (incl. spraying)	3) Yield increase in t/ha to cover: Product costs	Treatment costs
Weed control (Mono- and Dicotyledons)	methabenz-thiazuron	4.0	5.43	21.71	25.17	0.196	0.227
Growth regulator	cycocel	2.0	4.60	9.19	17.83	0.080	0.160
Weed control (Dicotyledons)	mecoprop	4.0	1.29	5.17		0.046	
Growth regulator	cycocel	0.5	4.60	2.30		0.020	
Pseudocercosporella herp.	carbendazim	0.3	10.76	5.43	19.16	0.049	0.173
E. graminis on leafs	triadimefon	0.5	16.03	8.01		0.072	
E. graminis on ears	triadimefon	0.5	16.03	8.01		0.072	
Septoria spp.	captafol	1.5	4.99	7.48	21.99	0.068	0.198
Insects	dimethoate	0.6	5.06	3.03		0.027	
Total				70.33	84.15	0.630	0.758

(LANGBEHN 1980)

1) Prices incl. V.A.T.

2) Application cost: £ 3.46/ha

3) Assuming winter wheat at: £ 110.85/ha
(incl. V.A.T. and drying costs)

1£ = 4.33 DM

COST EFFECTIVENESS OF WEED CONTROL IN BRITISH CEREAL GROWING

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The economic evaluation of herbicides in cereal production is bedevilled by the difficulty of making a financial interpretation of indirect benefits. This paper examines the role of weed control in the agronomy of the cereal crop in Britain and points out the importance of herbicides in sustaining modern cultivation and husbandry methods. Higher yields, and profitability, accrue from changes in production methods but these often rely on the efficacy of herbicides for their success.

The UK has become self-sufficient for all but certain strong bread wheats, a little durum wheat for pasta, and maize grain. In recent years barley, mainly of malting quality, has been exported to relieve our overall grain surplus. One obvious implication is that milling and bread-making quality for wheat and malting quality for barley will become increasingly important in governing price, or perhaps more directly in the ease of making a sale. Intervention buying may become a regular feature of the market - again with quality implications. For the farmer the market situation suggests that the price of grain is unlikely to keep pace with the effect of inflation on costs. Farmers will increasingly need to scrutinise the cost effectiveness of each input; this includes herbicides.

The Objectives of Weed Control

There are many reasons which can be put forward as justification for controlling weeds in cereals:

1. Direct effects

   i To maximise the profitability of the crop in which they are used by reducing weed competition;

   ii To minimise the return of weed seed to the soil and ultimately the population of weeds on the farm.

2. Indirect effects

   i The presence of weeds may slow down combining and increase harvesting losses, (this subject was discussed more fully by Elliott (1978) and at this conference)

   ii Weed seeds contaminate grain and can make it unsaleable for certain purposes - seed and intervention. Handling, drying and cleaning of weed contaminated grain is also more expensive;

iii During wet weather badly lodged crops can have their ears resting on a mat of wet weedy growth. This can encourage certain varieties to 'sprout in the ear' resulting in a loss of both yield and quality. The use of chlormequat on varieties with weak straw and the introduction of semi-dwarf varieties with good 'standing ability' has reduced the magnitude of this problem;

iv Weeds can be alternate hosts to pests and diseases. The British Weed Control Handbook (1977) refers to:-

Agropyron repens being associated with take-all (Gaeumannomyces graminis), and Alopecurus myosuroides with ergot (Claviceps pupurea), but the economic significance is difficult to assess. Survey evidence and advisory experience has shown the importance of volunteer cereal plants present in the autumn in promoting the spread of foliar diseases to the newly-sown crop. The control of these volunteer cereals with herbicides or stubble cultivations is increasingly important as winter cereal crops are sown progressively earlier;

More recently volunteers have been implicated in acting as a green bridge and increasing the incidence of Net-blotch (Pyrenophora teres). Infestation can be particularly severe where winter barley follows winter barley without ploughing;

v The increased efficacy and more intensive use of herbicides has allowed non-ploughing cultivation techniques to be developed. These methods of minimal cultivation permit a high work rate allowing more winter-sown cereal crops to be grown, (Patterson et al, 1980);

vi On many soils winter-sown cereals have a considerable yield advantage over the spring-sown crop. Evidence is accumulating that, with fungicides available, winter cereals can be successfully sown earlier than was accepted just a few years ago, (see Table 1).

Table 1

Effect of time of sowing on yield of winter barley (t/ha at 15% m.c.)

	Before 21 Sept	21 Sept to 7 Oct	7 Oct to 21 Oct	21 Oct to 7 Nov	7 Nov or later
1979					
High Mowthorpe			5.07	4.28	Failure
Boxworth		6.40	5.70		6.41
Gleadthorpe		6.42	5.83	5.81	
1980					
High Mowthorpe		4.94	4.61	4.24	
Boxworth	8.68	8.25	8.06		
Bridgets	7.31		5.24		
Gleadthorpe	8.04	7.54	6.78		
Rosemaund	7.77		6.77		

Source ADAS 1980

These early sown crops do not form a competitive canopy for 5-6 months and therefore rely more heavily on herbicides for weed control. Additionally, early-sown winter cereals allow less time for cleaning operations following the previous crop, putting more emphasis on the need for the use of effective herbicides. With later sowing dates more "cleaning" cultivations are possible before drilling.

Developments in Weed Control

1. Broad-leaved weed control

Experiments made by Blackman and Roberts (1950) in the period 1943 to 1947 showed an average improvement in the yield of cereals of greater than 20 per cent as a result of controlling weeds with herbicides. The widespread use of herbicides resulted in a diminution of weed populations and therefore less weed competition against crops. Evans (1966) reported on the effects of commercial treatments in experiments published from 1958 to 1964 and showed that the crop yield response to spraying with herbicides was generally quite small. Further, a survey carried out by NAAS (Evans 1969) between the years 1965 and 1967 compared the yield of cereals from sprayed and unsprayed areas at 297 sites on commercial farms. The results indicated that little or no yield would be lost by withholding herbicide for a year.

Experiments reported by Munro (1972) tested four chemicals and showed yield depressions of the order of 0.09 t/ha can occur when a range of herbicides were applied to winter wheat at the correct growth stage and correct dose. At double dose a mean yield depression of 0.13 t/ha was recorded, whilst delayed spraying caused a yield loss of 0.08 t/ha. Tottman and Phillipson 1974, and also Evans 1974, showed a yield loss associated with the late spraying of winter wheat with growth regulator herbicides.

The conclusion must be that farmers can no longer be assured of a yield increase from the use of herbicides to control broad-leaved weeds in the spring. Indeed, with the mis-matching of bouts and perhaps, in difficult seasons, with herbicides having been applied too late, a yield depression is to be expected from growth-regulator type herbicides.

More recently the trend has been towards using pre-emergence herbicides for broad-leaved weed control in winter wheat. Previously little winter wheat was sprayed in the autumn even though there has been a recommendation for the use of mecoprop in the autumn for a number of years. Evans (1978) reported on a series of experiments comparing autumn applied herbicides with normal spring applied herbicides for control of broad-leaved weeds in winter wheat. Autumn treatments with soil-acting (pre-emergence) herbicides were generally safe and effective in reducing weed populations, but on some sites chlortoluron and isoproturon were disappointing. Autumn applied growth-regulator herbicides gave similar results to the better residual herbicide treatments and, if chosen carefully according to weed species, could be a cheaper alternative to residual herbicides. There was a slight tendency for yields to be higher from autumn weed control compared with spring.

The competitive effect of weeds is generally best minimised by their removal early in the life of the crop. The trend for herbicide use in the autumn, I feel, will continue and is much helped by the development of low-ground-pressure vehicles and of spraying systems which allow the water volume applied to be reduced.

2. Grass weed control

Intensive cereal rotations, the maximisation of the area sown to winter cereals, and reduced cultivation systems, together with earlier sowing to achieve this objective, have dramatically increased the dependance on herbicides for the control of grass weeds. Indeed, many farmers are totally reliant upon herbicides to control grass weeds; their farming systems could not otherwise be sustained.

Moss (1979) reported that 54 per cent of the cereal-growing farms in England surveyed in 1977 were infested with Alopecurus myosuroides. Although traditionally associated with heavy clay soils, it is now increasingly a problem on lighter soils, particularly where successive crops of winter cereals are grown. The recent trend towards earlier drilling and replacing spring barley with winter barley has probably intensified the problem. A.myosuroides is favoured by tine cultivation and direct drilling; straw burning can limit the build-up of infestation. Moss (1979) demonstrated clearly how the effectiveness of some soil-acting herbicides can vary according to cultivation system. (see Table 2).

Table 2

Effect of cultivation system and straw disposal method on pre-emergence herbicide performance in winter wheat. (Moss 1979)

Percentage control of Alopecurus myosuroides

Cultivation system	chlortoluron 3.2 kg ai/ha straw baled	chlortoluron 3.2 kg ai/ha straw burnt	isoproturon 2.27 kg ai/ha straw baled	isoproturon 2.27 kg ai/ha straw burnt
Plough	95	95	73	57
Tine	67	94	45	80
Direct Drill	54	74	33	44

Pre-emergence applications of these herbicides may thus be less effective on direct drilled than on ploughed land, irrespective of straw disposal method. With tine cultivations, pre-emergence applications are likely to be effective when straw is burnt but may be less so if straw has been baled. However, post-emergence applications can be effective under all cultivation systems regardless of whether straw is burnt or baled. In the above experiment, a spring application of isoproturon (2.27 kg ai/ha) gave 98 per cent control.

Irrespective of a direct yield increase, the use of the herbicide could be cost effective on several counts, enabling:-

i the use of a reduced cultivation system;

ii the planting of a greater area of higher yielding winter cereals;

iii the rapid sowing of winter cereals near the optimum time.

3. Thresholds for grass weed control

Herbicides to control grass weeds are more expensive and require a yield response of approximately 0.5 t/ha to cover the direct costs of control. Experiments have indicated that it is likely to be worthwhile at 55 Alopecurus myosuroides plants/m^2 and 12 Avena plants/m^2 (North 1978). A distinction can be drawn between high yielding crops, which suppress weed growth, and crops with less vigour which suffer proportionately more from weed competition. Bowler (1973) constructed a graph showing a straight line relationship of yield increase to numbers of Avena panicles/m^2 controlled. Baldwin (1979) confirmed the threshold for Avena populations but for A.myosuroides pointed out that the value of predictive counts is limited as the weed emerges over too long a period, thus the herbicide should be applied early to remove weed competition. In the experiments reported by Baldwin (1979) there was no clear relationship between A.myosuroides numbers and likely yield response from herbicides, but rather yield response was more dependent on herbicide efficiency, crop vigour and soil fertility.

In recent years Bromus spp have been reported more frequently as a problem in winter cereals. Although Bromus sterilis is clearly the most important B.mollis and B.commutatus can be serious, for example, the latter at Boxworth EHF. These are weeds of a farming system, associated with repeated early sowing of autumn cereals after reduced cultivations or direct drilling.

There is at present little evidence on the competitive nature of the weed. However the cost effectiveness of herbicides in controlling a mixed infestation of Avena spp and B.sterilis can be seen from Table 3 (Tas, 1980).

Table 3

Effect of Avena and B.sterilis on yield of winter wheat

Herbicide	Panicles/m^2 Avena	Panicles/m^2 B.sterilis	Fertile tillers /m^2	Yield t/ha at 15% M.C.
Control	322	746	378	1.92
Tri-allate	117	578	370	4.18
Metoxuron	171	292	401	4.87
Tri-allate + Metoxuron	8	117	495	6.45
				SED $\pm$ 0.505

Drayton EHF

The herbicide treatments in this experiment were:-

i Control - no herbicide

ii Tri-allate at 1.70 kg ai/ha - post drilling, harrowed in

iii Metoxuron 4.37 kg ai/ha - applied at 2-3 leaf stage of weed in autumn with added wetter

iv Tri-allate + Metoxuron as given above

Screening work suggests that the weed tolerates most herbicides used to control Alopecurus and Avena in cereals, although the sequential use of tri-allate and metoxuron has been shown to give moderate control. Cultural control measures involve avoiding those husbandry practices that have encouraged this weed to become a problem. Delayed sowing may be only partially successful in non-ploughing situations since in dry autumns the weed seed does not germinate and cannot therefore be killed by cultivations. Deep burial of the weed seed by mouldboard ploughing may give useful control but this involves disturbance of the type of soil structure build up under direct drilling. Careful hygiene with a cultivated sterile strip around the hedgerows and the use of more intensive cultivations and herbicides on the headlands may prevent the rapid ingress of the infestation to the whole field. In some situations it may prove to be cost effective to alter cropping and grow a break crop in which an efficient grass weed herbicide can be used.

4. The problem of Poa spp

Much of the cereal growing area of the country is infested with either annual meadowgrass (Poa annua) or rough meadowgrass (Poa trivialis). Where herbicides are used to control other grass weeds then the Poa spp are well-controlled. In certain cereal growing areas Alopecurus myosuroides and Avena spp are not a major problem but severe infestations of Poa spp may justify control measures. An experiment was started in 1979 at Rosemaund EHF to determine the yield responses from control of Poa spp. In 1979 the experimental site was almost free of weeds and therefore provides useful information of the effects of herbicides on the crop in the absence of weed competition. (Table 4).

Table 4

Effect on crop yield (t/ha) of control of Poa spp by herbicides. Rosemaund EHF

Time of herbicide application

Herbicide	Pre-emergence	Post-emergence autumn	Post-emergence spring
1979			
Methabenzthiazuron	7.86	7.45	7.66
Chlortoluron	8.02	7.86	6.80
Isoproturon	7.46	8.09	6.50
Terbutryne	7.34		
Control	7.90		
		S.E. ± 0.383	
1980			
Methabenzthiazuron	8.87	8.56	8.39
Chlortoluron	8.68	8.58	8.35
Isoproturon	9.14	8.84	8.33
Terbutryne	8.85		
Control	8.46		

The rates of application of herbicides in this experiment were:-

Herbicide	Pre-emergence and Post-emergence autumn	Post-emergence spring
Methabenzthiazuron	1.58 kg ai/ha	1.58 kg ai/ha
Chlortoluron	3.50 kg ai/ha	2.75 kg ai/ha
Isoproturon	2.50 kg ai/ha	2.10 kg ai/ha
Terbutryne	1.50 kg ai/ha	-

In autumn 1979 the germination of the winter wheat seed was delayed due to dry and cobbly seedbeds and there was little competition from Poa spp. The autumn post-emergence treatment was delayed by the severe winter until 8 March; the spring post-emergence treatment was made on 27 April at GS 30 to 31. In the absence of weed competition, yields, after treatment with chlortoluron and isoproturon post-emergence at GS 30 to 31, were reduced. Phytotoxicity symptoms were observed.

In 1980 high numbers of mainly Poa annua were encountered (98 plants/m^2 on the control plots) and yield responses to herbicide treatment were obtained. There was a tendency for the better crop yield responses to be obtained from the pre-emergence application. Yields were slightly depressed by the spring GS 30 application of herbicide although Poa spp was well-controlled; presumably any small beneficial effect gained by removing weed competition at this late stage was negated by phytotoxic effects on the crop.

Summary of the current situation

i Experiments have shown the importance of early control of weeds in the autumn and early winter, when a yield response may be obtained which cannot be matched by later removal of weed competition;

ii Herbicide mixtures are available which will control broad-leaved weeds in the autumn without damaging the crop;

iii Other herbicides which control Alopecurus myosuroides and Avena spp are also effective against Poa spp and many broad-leaved weeds;

iv The development of autumn and early winter herbicide treatments have relieved the pressure on the relatively few available spraying days in the spring when mis-timed applications of growth-regulator type herbicides can cause crop damage.

v Late germinating weeds are not so competitive, but can return seed to the soil. It is especially important in the case of grass weeds to prevent seed return adding to the soil reservoir. Sequential use of herbicides, although expensive, can prevent fresh seed returning to the soil;

vi Herbicide mixtures are capable of controlling virtually all weed populations. However, following autumn treatment there are certain problem weeds such as Galium aparine (cleavers).

vii Low volume spraying techniques and low-ground-pressure vehicles can help overcome the problem of applying herbicides when soil conditions are adverse.

Weed competition as a constraint on crop yield

The attainment in recent years of some very high yields of winter wheat has foocussed attention on the concept of maximum potential yield. An important simplification of the theoretical work is the prediction that the rate of dry matter produetion, by any crop, early in the growing season, is proportional to the amount of light intercepted by its foliage (Biscoe and Gallagher, 1977). In modern varieties of winter wheat approximately 50 per cent of this dry matter is in the form of harvested grain (Austin and Jones, 1976). When there are no other constraints to growth physiologists have calculated that 12 to 15 t/ha of wheat grain can be produced. When growth is restricted - by climate, soil, pest, disease, management or competition by weeds - the actual efficiency with which intercepted light is used is reduced.

Based on these premises, crop physiologists have produced 'Blue-prints' to achieve near maximum yield and 'systems of production' to consistently achieve high yields. The main conclusions from experiments carried out by ADAS are:-

i High levels of inputs have not always produced very high yields, indicating that some constraint, other than those rectified by the experimenter, limited yield;

ii Soil type and particularly the water retention ability of the soil was important. Very high yields were usually achieved on moisture retentive soils where the crop could maintain an active root structure to below 1 m depth;

iii The lavish use of inputs; pesticides, growth regulators and fungicides was no guarantee that a high yield could be achieved.

It is noteworthy that neither weed control nor varying herbicide inputs were tested in these or in multifactorial experiments. The experiments make the assumption that weed competition should be removed by the adequate use of herbicides since weed dry matter production must arise at the expense of crop dry matter yield. Baldwin (1979) produced evidence which supported this view. Where Avena fatua was efficiently controlled by benzoylprop-ethyl at GS 31 the grain yield increase showed almost a direct substitution with the weight of wild-oat panicles obtained from plots not treated with herbicide. The results of this series of experiments show good yield responses from herbicide application up to the second node stage, but thereafter the wheat crop was unable to compensate with increased yield as a consequence of the removal of weed competition.

The cost effectiveness of herbicide use has not been determined in high-yielding, multifactorial experiments. It could be argued that at £100/t and a yield of 8.77 t/ha herbicide costs of £32/ha are insignificant; this was the situation at Rosemaund EHF for 1980 harvest. However, the high-yielding crop may have a higher level of crop vigour and can more likely suppress young seedling weed growth. It may be a false assumption to aim for a weed-free crop under those conditions as the phytotoxic effect of some herbicides could negate any small yield response arising from the removal of weed competition.

In contrast more than half the UK winter wheat crop yields less than 5 t/ha and, although there must be scope for great improvements, it should not be ignored that much of this area has natural constraints to yield such as climate, soil type and available water. Where yield potential is restricted it is perhaps more vital to quantify carefully the cost effectiveness of each input. An intensive cereal grower with a yield of 5 t/ha may need to control Avena spp, Alopecurus myosuroides, perhaps Poa spp and a range of broad-leaved weeds. This may cost £75/ha which represents 15 per cent of gross output compared with less than 4 per cent at Rosemaund EHF.

Clearly, in the case of the intensive cereal farm, herbicides must be regarded as an annually recurring charge needed to maintain a farming system which has the attribute of lower fixed costs. The introduction of arable break crops may increase gross output and reduce the weed control problems, but will increase fixed costs. Similarly, the introduction of livestock enterprises may assist in reducing the weed control problems, but would perhaps reduce output and raise capital investment. The real cost effectiveness of herbicides in UK cereal production lies not only in the direct effect of increased yields from reduced weed competition, but the freedom they confer on farmers to crop according to market trends and to adopt new husbandry practices which may increase yields.

References

ADAS (1980) Private communications

AUSTIN, R.B. and JONES, H.G. (1976) The physiology of wheat. Annual Report of the Plant Breeding Institute, Cambridge for 1975, 20-73

BALDWIN, J. (1979) The chemical control of wild oats and blackgrass. A review based on results from ADAS agronomy trials. ADAS Qtly Review 33, 69-101

BLACKMAN, G.E. and ROBERTS, H.A. (1950) Studies in selective weed control, II. The control of annual weeds in spring cereals. J. Agric. Sci. 40, 70-81.

BISCOE, P.V. and GALLAGHER, J.N. (1977) Weather, dry matter production and yield. Environmental Effects on Crop Physiology, Academis Press, London, 75-100

BOWLER, D.J. (1973) Economic benefits from controlling wild oat. Span, 16, 79-81

ELLIOTT, J.G. (1978) The economic objectives of weed control in cereals. Proceedings 14th British Weed Control Conference, 3, 829-839

EVANS, S.A. (1966) A review of the present position in cereal weed control and an introduction to research reports. Proceedings 8th British Weed Control Conference, 3, 753-62

EVANS, S.A. (1969) Spraying of cereals for the control of weeds. Expl. Husb. 18, 102-9

EVANS, S.A. (1974) The timing of post-emergence herbicide spray applications for broad-leaved weed control in cereals. Proceedings 12th British Weed Control Conference, 3, 967-976

EVANS, S.A. and HARVEY, J.J. (1978) Annual broad-leaved weed control in winter wheat, autumn and spring treatments comp d. Proceeding 14th British Weed Control Conference, 1, 41-47

MOSS, S.R. (1979) Black-grass - a threat to winter cereals. Weed Research Organization. Technical Leaflet No.15

MUNRO, I.A. (1972) Late spraying of winter wheat. Proceedings 11th British Weed Control Conference, 717-21

NORTH, J.J. (1978) Pesticides in cereal production. Pesticide Science, 9, 234-239

PATTERSON, D.E., CHAMEN, C.T. and RICHARDSON, C.D. (1980) Long term experiments with tillage systems to improve the economy of cultivations for cereals. J. Agric. Engng. Res. 25, 1-35

TAS, M.V. (1980) Private communication

TOTTMAN, D.R. and PHILLIPSON, A. (1974) Weather limitations on cereal spraying in the spring. Proceedings 12th British Weed Control Conference, 1, 171-176

THE ECONOMIC SIGNIFICANCE OF WEEDS IN THE HARVESTING OF GRAIN

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For the 1978 Weed Control Conference I prepared a paper (Elliott, 1978) that was an attempt to analyse the ways in which weeds interfered with the production, harvesting and marketing of grain. During its preparation I detected issues which were too deep and complex to be handled satisfactorily in the time available and so resolved to continue my studies.

THE CONCEPT OF ADDED VALUE AND THE INTERFERENCE CAUSED BY WEEDS

There is only one point at which a true value can be assigned to a tonne of grain and that is at the actual point of sale. Although the buyer may quote a price on farm, it will take into account all the expenditure necessary to get the sample to the state and the place that he wants it. Everything that happens to grain costs money; and this includes harvesting, transport to store, drying, storage, cleaning and transport ex farm. On the one hand a sample of grain loses value as it gets further back from the point of sale, and on the other grain standing ripe for harvest in the field adds in value at each successive stage to point of sale (Fig. 1). Grain may lose value through a general drop in market prices or a farmer may increase its value by intelligent trading, but these are modifying influences on the general tendency to increase in value with time, storage and processing. If weeds had no differential effect on the process of added value they would have no significance. It is my contention that weeds present at harvest time affect the costs of handling grain from harvest onwards and therefore the process of added value. The forms of weed interference need to be understood and quantified because differences in costs necessitate a different value put on grain standing ripe in the field and affect decisions about weed control in the growing crop.

COSTS OF HARVESTING, DRYING, STORING AND MARKETING GRAIN

In Table 1 are set out some figures of costs with an indication of their origin and the way in which they have been calculated. These figures are believed to be reasonably typical of the situation prevailing at 1980 harvest. It is unlikely that they take into account weeds: the compilers of the figures do not mention whether they do or not. Some costs defy calculation, these are mostly the ones that occur when the grain leaves the farm. Transport costs and merchants' handling costs are known only to them. Careful enquiries within the trade have not indicated any reliable average figure which could be used. In consequence such charges are not included and, because of their exclusion, those that are probably underestimate the process of added value.

In Table 1, the ascertainable costs vary between a low of £32.79 and a high of £45.21. The difference arises from different approaches to the estimating process and has nothing to do with weeds. It seems likely that a crop valued at £100 a tonne clean and dry in the merchant's warehouse in say February would be likely to have a value of only £60-£70 a tonne when standing ripe ready for harvest. Although weeds probably add to the costs of all the processes mentioned evidence has been collected only about the first and most important process, namely combine harvesting.

Table 1

Estimates of costs of crop processing from harvest, 1980
in £ per tonne of grain from an averagely clean crop

		£/t
Combining		
NAAC* quoted price less 10% deduction for profit, and on the basis of a 5 t/ha crop		10.36
ADAS suggestion of £41.60/ha		8.32
Conveyance to store		
NAAC quoted price, and as above		3.25
ADAS suggestion of £10/ha for 1980		2.00
Combining and conveyance to store		
NAAC quoted price, less 10%		13.61
ADAS suggestion of £51.60/ha for 1980		10.32
Drying and ventilation		
Average figure for 1979 from Farmers Weekly, 15.2.80, + 15%		1.44
Storage on farm for 6 months		
Cherrington BFS 22 Sept 79 + 15%		22.48
Petrie, Big Farm Management, Dec 79 + 15%		20.77
Theophilus (ADAS) for 1980		31.60
Transport ex farm	no average figure ascertainable	
Merchants' handling and cleaning	no average figure ascertainable	
Total of ascertainable costs	low	32.79
	high	45.21

* National Association of Agricultural Contractors Guide prices, 1980

COMBINE HARVESTING AND THE IMPORTANCE OF MATTER OTHER THAN GRAIN

The passage of a combine harvester through a standing crop in order to cut, collect, thresh, sieve and retrieve the grain is a highly complex process contained all in one machine. Losses can and do occur at every stage. Even before the combine harvester moves into the field, shedding losses may have occurred. Engineers distinguish between front end losses (shedding and on the cutterbar) and threshing losses (from drum, sieves and straw walkers).

Shedding losses

Klinner (1979) has described how losses occur before harvest. The normal progression of shatter losses in wheat and barley is from ca 100 kg/ha 20 days from the start of shedding to 300 kg/ha 40 days after the start. An unharvested crop is subject to progressive shedding and deterioration. Actual harvested losses also increase with time regardless of the harvesting method used. Therefore it is economically sound to plan for minimal delay after the crop has reached maturity.

Examples of the financial consequences of delayed harvest have been provided by Bell (1977). A study of cereal crops in the north-east of Scotland showed that for a 121 ha harvest with grain valued at £80 per tonne and yields of 4.65 t/ha the financial consequences of delay ranged from £1900 (about £16/ha or £3.4/t) for a new machine operating in Moray to £6000 (£50/ha or £10.8/t) for a 10-year-old machine in Caithness. The majority of the additional loss being a result of slower working speeds.

The inference is that a factor (which, as we will see, could be weeds) which slowed down the speed of working of a normal combine would contribute to the losses as much as would the use of a slow-working machine.

Threshing losses

Many authors (Klinner, 1979; Fairbanks et al., 1978; Busse, 1977; and Cooksley, 1980) have pointed to the relationship between threshing losses and the throughput of material through the combine. Although some authors refer to total throughput most link losses to the parameter of 'matter other than grain' (MOG). MOG is everything which goes into the combine which is not grain (straw, chaff, weeds etc). According to Arnold (1980) an increased throughput of MOG increases the thickness of the layer passing over the walkers and sieves: beyond a certain thickness grain cannot easily fall through and is ejected with the MOG. At normal throughputs losses are modest and increase only a little with increased throughput of MOG to a certain limit of tolerance above which losses escalate with further increase in throughput of MOG in tonnes per hour. The efficient working of a combine lies in operating at a throughput of MOG short of the part of the curve where escalation of losses occurs. Publications on this subject do not, surprisingly, remark on the significance of weeds.

If the effect of increasing a combine's ground speed is to increase the throughput of MOG it is also true that, without an increase in speed, an increase in the weight of MOG per unit area must result in an increase in throughput of MOG. Herein lies the significance of weeds: certain types of weeds have a major impact on MOG weight per unit area. A further aspect of this relates to the moisture content of the material. A clean ripe cereal crop may contain material which is less than 20% moisture content: there are certain types of weed which, having ripened by harvest, would have a similar moisture content. However there are others, particularly perennial weeds and in wet years, which would still be growing vegetatively. With these there would be not only a greater bulk of material present but a higher moisture content. Since MOG appears to be estimated by engineers at a field weight; green weeds could have a very significant effect on weight of MOG per unit area.

THE EFFECT OF WEEDS ON MOG

Clearly the abundant presence of a weed in a cereal crop, particularly if it is green, should tend to increase the total bulk of material present. If this is the case then the combine will be slowed and the time taken to cover a hectare will be increased. There is then an absolute increase in the cost of harvesting the area. However there could be situations in which the presence of weed is counteracted by the absence of crop. Were this to occur there might not be a great difference in the weight of MOG per unit area but there would still be a significant difference in the cost of harvesting the grain because the time taken per tonne of grain would be greater. The first situation can be considered in terms of weight of MOG per m^2, the second situation is better catered for by the ratio of grain to MOG. In many respects this ratio is the most meaningful relationship to consider because it is only in terms of the weight of retrieved grain that the harvesting operation can be paid for.

Normal situations in clean cereals

In both wheat and barley crops grown normally and free of weeds it is usual for there to be 5-10 t/ha of MOG. The weights are often about similar to the weight of the grain; and in this situation G:MOG ratio would be about one. Pearman, Thomas and Thorne (1978) have published analyses of some dwarf and tall wheats after the use of a range of nitrogen levels; the results show how similar the weights of G and MOG can be, giving a ratio around one. However they demonstrated that a tall wheat such as Capelle may have a slightly lower ratio than a semi-dwarf wheat such as Hobbit and therefore presumably incur a small extra cost of harvest. Similarly Elliott, Ellis and Pollard (1977) have published analyses of spring barley grown by direct drilling, shallow or deep tine cultivation or ploughing. In two years the G:MOG ratios were slightly over one with no difference between cultural treatments. In the third year the ratio was slightly below one. No doubt the literature contains many other figures for clean crops.

The presence of wild-oats

There are many publications concerned with the effects of wild-oats on the growth and yield of cereals but very few which allow analysis of G:MOG ratios. However Peters (1978) produced figures for several experiments in Oxfordshire in 1972-73 where wild-oats occurred naturally in spring barley (Table 2). An examination of the total MOG figure shows that in most experiments the presence of substantial numbers of wild-oats caused only a small increase in the weight of MOG. This was because the competition from the wild-oats reduced the quantity of crop straw present and ripening reduced the moisture content of the wild-oat straw. However an examination of the G:MOG ratio shows striking differences at some but not all of the sites. At Cuddesden in 1972 the ratio of 0.76 with the clean crop was reduced to 0.46 and at Fyfield in 1973 a ratio of 1.18 was reduced to 0.53. However in the same year at Streatley 0.96 for the clean crop was reduced more modestly to 0.70. It seems clear from this that the effect of the wild-oat on barley yield coupled with a modest increase of MOG compounded to make a very significant effect on harvesting at some of the sites.

Table 2

Effect of wild-oats on spring barley grain and MOG, 1972 and 1973

			Grain yield t/ha	MOG t/ha	G:MOG ratio
1972	Cuddesden	clean	3.39	4.44	0.76
		weedy	2.51	5.40	0.46
	Fyfield	clean	5.20	5.60	0.93
		weedy	5.07	6.26	0.81
1973	Cuddesden	clean	4.85	3.79	1.28
		weedy	4.12	4.30	0.96
	Fyfield	clean	4.62	3.93	1.18
		weedy	2.79	5.22	0.53
	Streatley	clean	4.12	4.30	0.96
		weedy	3.11	4.42	0.70

From Peters, N.C.B. (1978), Agricultural Research Council Weed Research Organization, Ph.D. thesis.

The effect of an annual broad-leaved weed is provided by Aspinall and Milthorpe (1959) in a competition study between Polygonum lapathifolium and the barley. The ability of the weed to grow strongly from the 8th week after planting caused a major increase in its content in the barley crop at harvest.

Agropyron repens

Research undertaken in the 1960's to provide a biological basis for the control of couch grass provides evidence of contamination at harvest (Table 3). By planting a low and high population of rhizomes in spring wheat, spring barley and spring beans Cussans (1970) caused couch grass to grow in these crops. Whereas the ratio of G:MOG in the clean crops was normal in the range of 0.71 to 1.44 the presence of the weed caused dramatic reductions. Even the low population of couch caused ratios of 0.33 in the wheat and 0.38-0.48 in the barley while the beans were so infested by the weed that harvesting might be considered impossible. The dramatic decline in the ratios happened because of substantial green growth of the couch during August, fresh weights in excess of 20 t/ha being recorded in the wheat and barley.

No doubt these values would be very markedly affected by the summer rainfall but it is precisely in the wet years that there is pressure on harvesting and a weed such as couch grass would be at its most damaging.

Table 3

Effect of Agropyron repens (couch) on amounts of wheat and barley present on 21 August 1970

Crop	Rhizome density	Barley t/ha grain	Barley t/ha non-grain	MOG t/ha couch & straw	G:MOG ratio
S wheat	nil	3.89	5.46	5.46	0.71
(Kloka)	low	3.46	5.78	10.48	0.33
	high	2.36	4.98	25.68	0.09
S barley	nil	4.36	3.96	3.96	1.10
(Impala)	low	4.16	3.73	11.03	0.38
	high	3.67	2.97	27.07	0.14
S barley	nil	4.74	3.29	3.29	1.44
(Deba)	low	4.66	3.25	9.65	0.48
	high	3.88	2.90	33.00	0.12

(Cussans, 1968: the figures are for cutting at ground level and would be slightly modified if a combine had been used)

Agrostis gigantea

The only evidence that has been found on this weed is a pot experiment by Mann and Barnes in 1949, various ratios of barley seeds and root pieces of the weed being planted. The results generally confirm the findings by Cussans for Agropyron repens in that the ratio of G to MOG was reduced from a maximum of 0.93 for the clean crop to 0.30 in the case of the most competitive planting of Agrostis gigantea. An experiment by Mann and Barnes in 1934 involving the competitive planting of barley and Holcus mollis produced similar effects.

Alopecurus myosuroides

During the harvesting of a WRO experiment on winter barley in Oxfordshire in

July 1980 the weights of grain and MOG emerging from a combine were recorded (Table 4). The major competitive weed was black-grass, and where it was controlled the yield of grain and MOG was similar to that of the clean crop. Although there were broad-leaved annual weeds present their control alone did not increase grain yield compared with the weedy crop: it did however lead to the lowest figure of MOG (10.24 t/ha).

Failure to control the weeds, particularly the black-grass, caused a major reduction in G:MOG ratio from 0.71 in the clean crop to 0.33 in the weed infested. If throughput of MOG were the limitation on combine performance it would have taken more than twice as long to harvest a tonne of the grain in the presence of black-grass as in its absence. It is interesting to note that the total material on offer to the combine was very similar in the range of 17-19 t/ha but the processing of the clean crop yielded 8 t/ha grain and that of the weedy only 4.4 t/ha.

Table 4

Material combine harvested from cereal crops infested with black-grass and broad-leaved weeds, on which herbicides were used

	Weed control			
	Nil	Black-grass only	Broad-leaved only	Black-grass + broad-leaved
Winter barley, 24 July 1980				
grain yield t/ha	4.36	8.15	4.59	8.00
MOG t/ha	13.10	10.76	10.24	11.24
length of straw cut cm	54	61	59	67
G:MOG ratio	0.33	0.76	0.45	0.71
Winter wheat, 22 Aug 1980				
grain yield t/ha	3.1	4.6	5.4	9.2
MOG t/ha	10.8	10.9	11.0	11.2
G:MOG ratio	0.29	0.42	0.49	0.82

An autumn wheat experiment near Oxford containing black-grass and Galium aparine (cleavers) was harvested by combine in late August 1980. The opportunity was taken of recording MOG as well as grain on some of the treatments; the results are in Table 4. This wheat experience is an interesting contrast to the winter barley because both black-grass and the broad-leaved weeds (mostly cleavers) were competitive with the wheat and reduced grain yield. In late July the black-grass was ripening but the cleavers looked massive and green: however, they too ripened and dried to give MOG yields that were very similar on all treatments. Failure to control some or all of the weeds resulted in a reduction in G:MOG ratio from 0.8 to 0.5 or less, with consequent increase in the cost per tonne of harvesting the grain.

The two experiments show a puzzling contrast. In the winter barley a good end yield of grain and MOG was achieved by controlling only the black-grass; but in the winter wheat all the weeds had to be controlled to achieve a good end result.

THE FINANCIAL SIGNIFICANCE OF WEEDS AT HARVEST

If the limitation on a combine's forward speed is the throughput of MOG per hour, and the relationship between grain and MOG is known; it should be possible to quantify the cost of harvesting a tonne of grain in different situations of MOG.

The cost of a combine harvester is on a time basis. Interest on capital, annual depreciation, insurance, maintenance, cost of driver and fuel, are all calculated in time. Some are regardless of time in use, others are according to time in use. The operating cost per hour of use is the figure most commonly accepted as relevant. Obviously large combines cost more per hour to run than small combines but they process more MOG and hopefully more grain in an hour's work. If one assumes that average costs per ha for combining are based on average crops (5 t/ha grain and G:MOG ratio of 1), the cost of processing a tonne of MOG can be calculated.

		£/t MOG
1.	At NAAC price of £57.57/ha a contractor would charge	11.51
2.	ADAS E. Region suggestion of £41.60/ha	8.32

Clearly it is not the absolute figure that is important since this will vary in different crops and with different efficiencies of driver operation, but the order of figure involved. It seems reasonable to suggest that in an averagely clean crop in 1980, it cost about £10 to process a tonne of MOG.

What impact would weeds have on the cost of harvesting the grain? As has already been shown weeds can have one of three effects. Either they increase the weight of MOG/m^2 or they do not alter it but alter the G:MOG ratio. Thirdly they may alter both parameters.

Increase in weight of MOG/m^2 without reduction in grain yield.

When the combine driver approaches a weedy area, he is likely to slow down to regulate the MOG intake of the machine and thereby avoid increased grain loss; or he can continue at the same speed accepting the increased grain loss. The possibility of raising the cutter-bar is unlikely because all too often weeds drag down the crop and if anything require a lowering of the cut.

Combine slows down: as the machine moves from clean to weedy crop there is an increase in MOG/m^2 and a reduction in G:MOG ratio even though grain yield/m^2 is not reduced, and less grain is retrieved per tonne of MOG. The increased cost of retrieving the grain (Table 5) is relatively modest for changes of 0.1 or 0.2 in G:MOG ratio but thereafter it escalates such that at ratio of 0.5 doubles the cost of grain retrieval.

Table 5

Cost of harvesting a tonne of grain at different ratios of G:MOG in a 5 t/ha crop at £10/t MOG

G:MOG	Cost £/t grain	G:MOG	Cost £/t grain
1.0	10.00	0.5	20.00
0.9	11.10	0.4	25.00
0.8	12.50	0.3	33.30
0.7	14.30	0.2	50.00
0.6	16.70	0.1	100.00

In practical terms an infestation of couch, black-grass or cleavers in a 5 t/ha crop which reduced the G:MOG ratio from 1.0 to 0.5 would, on this calculation, increase the cost of harvesting by £50/ha. But a more likely situation is that weed competition would reduce the weight of grain and straw present, and the main additional cost would be per tonne of grain with only a modest increase in cost per hectare.

Combine does not slow down: in the event of the combine being able to process the increased material and the driver being prepared to ignore the warnings of the grain loss monitor; MOG throughput would rise, increasing the thickness of vegetation on the walkers, and increasing the threshing losses.

Cooksley (1950), Klinner (1979), Fairbank et al. (1978) and Busse (1977) have published graphs illustrating and quantifying the escalating losses that occur with increasing throughput of MOG beyond the point of efficient separation. A test by Cooksley (1980) conducted at the National Institute of Agricultural Engineering will illustrate the principle (Table 6).

Table 6

A crop of Mazurka spring barley of moisture content 17-21% was harvested by an International 953 combine; the yield is assumed to be 5 t/ha (worth £70/t prior to harvest) and the ratio of G:MOG to be 1

NIAE data		My calculation		
MOG throughput tph	Grain loss %	Wt of loss kg	Cost of harvest £/t	Value of grain loss £/ha
8.0	0.5	40	10.0	1.7
9.0	3.5	280	11.7	12.2
9.5	10.5	840	13.3	36.7

Clearly the line between minor and major loss was extremely narrow: a mere 1.5 tph extra MOG being enough to cause a major loss. My calculations show that the main financial loss was from grain not retrieved: there was little extra cost per hectare of combining.

Reduction in grain yield without increase in MOG/m^2

If there were no increase in MOG/m^2 and the weeds were able to pass through the combine; the driver would continue to work at unchanged throughput and speed. He would harvest less grain per hour because the G:MOG ratio is reduced. The cost of retrieving a tonne of grain would therefore be increased, and in accordance with the calculations in Table 5. For example, a decrease in G:MOG ratio from 1.0 to 0.5 would increase the cost by about £10 per tonne.

Reduction in grain yield and increase in MOG/m^2

This is the most damaging situation likely to occur in weed infested crops harvested late in a wet year. Shedding losses, and those described in Tables 5 and 6 may all be at work simultaneously. There are no field data upon which to base a reliable calculation.

CONCLUSION

Clearly weeds present at harvest have a major impact on the cost of harvesting the grain. In seeking to quantify the costs I have used figures which are open to adjustment. Even so they indicate the magnitude of the sums involved.

Weeds differ in their impact on the situation. Annuals which ripen with the crop cause little increase in MOG per unit area; the damage they cause is through the G:MOG ratio. In contrast perennials which continue to grow vegetatively do their damage mostly by increasing MOG per unit area. Now that attention has been drawn to the significance of weeds at harvest, they should be categorised in terms of MOG and G:MOG in different crops. It is particularly important to identify those weeds which compete early in the life of the crop and grow late in its life, because they are the most damaging.

What order of herbicide cost is justified to escape the perils described in this paper? To see the issues clearly it is necessary to stop using the hectare as a measure of input and start using a 'tonne of expected grain yield'. This is fair because at the end of the day it is the grain that will pay for the costs. Unfortunately herbicide costs are on an area basis, so a conversion is necessary (Table 7).

Table 7

Herbicide cost per tonne of expected grain yield

Herbicide cost £/ha	Grain yield t/ha 4	5	6	7	8
10	2.5	2.0	1.7	1.4	1.2
20	5.0	4.0	3.4	1.4	1.2
40	10.0	8.0	6.8	5.8	5.0
60	15.0	12.0	10.2	8.7	7.5

By putting together Tables 5, 6 and 7 it is possible to gain some appreciation of the link between herbicide costs and harvesting efficiency. In the typical 5 t/ha crop used before in this paper the prevention of a modest drop by 0.3 in the G:MOG ratio would justify an expenditure of £20/ha; and a decision by the driver to press on (as in Table 6) could well lead to losses in excess of £20/ha. The justification is in terms of increased harvest cost and is on top of the justification based on preventing yield reduction due to weed competition.

It is surprising that so little attention has been paid to weeds at harvest in the thirty years that combines have been in use in British agriculture and doubly surprising that combine engineers have not complained at the abuse of their machines by weeds. When one includes the role of the combine in spreading weed seeds, it appears that weed technologists and combine engineers should communicate better in the future than they have in the past.

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I wish to acknowledge the assistance of members of the Annual Crops Group of WRO (B.J. Wilson, M.E. Thornton and P.A. Phipps). After poring over the excretions of combines, they might be forgiven for thinking that MOG stands for 'Mostly Obnoxious Grime'. Thanks are due to Miss B.E. Watson for her careful preparation of the script.

References

ARNOLD, R.E. (1980) The National Institute of Agricultural Engineering, Silsoe, Beds. Private communication.

BELL, W. (1977) The cost of combine breakdowns and delayed harvesting, Farm Management Review, 10, 29-40.

BUSSE, W. (1977) The design and use of combine harvesters for minimum crop loss, Agricultural Engineer, 32, 3-5.

COOKSLEY, J. (1980) Rotary combine gets 'thumbs up' from NIAE, Arable Farmer, January, 71-72.

CUSSANS, G.W. (1968) A study of the ratio of shoot and tiller emergence of barley and Agropyron repens (L.) Beauv., Proceedings 9th British Weed Control Conference, 137-141.

ELLIOTT, J.G., ELLIS, F.B. and POLLARD, F. (1977) Comparison of direct drilling, reduced cultivation and ploughing on the growth of cereals. 1. Spring barley on a sandy loam soil, Journal of Agricultural Science, Cambridge, 89, 621-629.

ELLIOTT, J.G. (1978) The economic objectives of weed control in cereals, Proceedings British Crop Protection Conference (Weeds), 829-841.

FAIRBANKS, G.E., JOHNSON, W.H. and SCHROCK, N.D. (1978) Field comparison of rotary and conventional combines in wheat, American Society of Agricultural Engineer's Paper No. 78-1591.

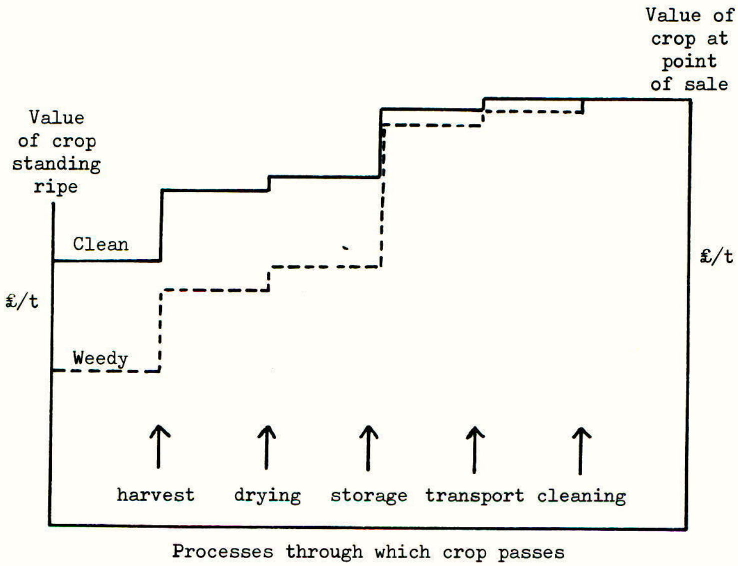
KLINNER, W.E. (1979) Reducing grain losses in harvesting operations, Agricultural Engineer, 34, 23-27.

PEARMAN, I., THOMAS, S.M. and THORNE, G.N. (1978) Effect of nitrogen fertilizer on growth and yield of semi-dwarf and tall varieties of winter wheat, Journal of Agricultural Science, Cambridge, 91, 31-45.

PETERS, N.C.B. (1978) Agricultural Research Council Weed Research Organization, Ph.D. Thesis.

Fig. 1

The addition of value to a tonne of grain



NOTES

THE INTEGRATED CONTROL OF WEEDS IN THE MAIZE CROPS OF ROMANIA USING DIFFERENT HERBICIDES

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Summary Maize crops in Romania are infested by various species of annual and perennial weeds, the most frequent throughout the country being Sinapis arvensis, Setaria glauca, Setaria viridis, Echinochloa crus-galli Amaranthus spp. Chenopodium album, Polygonum spp. Cirsium arvense, Convolvulus arvensis, Sorghum halepense etc. Under these conditions, the total control of annual and perennial weeds was achieved only by the use of herbicide mixtures or repeated applications. The authors describe the results obtained on the main soil types of Romania with various herbicides applied either singly or as mixtures, i.e. atrazine, cyanazine, linuron, alachlor, butylate, EPTC + antidote,etc. On the basis of the experimental results, several models which allow the eradication of weeds in maize crops was advanced.

INTRODUCTION

The progress achieved in the field of plant breeding resulted both in Romania and in other countries in the development of maize hybrids able to yield 6,000-8,000 kg grain per hectare on non-irrigated fields and 10,000-14,000 kg on irrigated ones. Such yields could only be obtained in maize crops in which it was possible to realize total control (eradication) of annual and perennial weeds. Weed eradication can also be achieved by the use of such classical methods as: ploughing, discing, mechanical and/or manual hoeing, etc. and the application of rational crop rotations. Such practices are hardly used now due to shortage of manpower in agriculture.

For these reasons, the chemical control of weeds is now promoted throughout the world. Maize technology went through radical changes after the release of the early herbicides atrazine and simazine. Due to their outstanding selectivity to maize plants and their effectiveness against a wide range of annual weeds, both herbicides are still important world-wide, being used in many countries, (Voevodin, 1964; Liubenov, 1970; Kasassian, 1971; Krafts, 1975; Klingman, 1975; Sarpe et al 1975; Behrens, 1979; Aman, 1979). Lately due to the prolonged persistence of atrazine and simazine and their ineffectiveness in the control of perennial weeds, integrated control methods consisting of sequences of different herbicides were used. As pointed out by Romanowsky (cited by Fryer and Matsunaka, 1977) in the integrated control of weeds in maize in the USA about 20 different herbicides are used at a variety of times. The present report describes the results obtained so far in Romania in the integrated control of weeds.

METHOD AND MATERIALS

For the total control (eradication) of annual and perennial weeds, trials were carried out in all important areas of Romania, using different herbicides applied either singly or as mixtures, at the rates given in table 1. The trials also included repeated treatments.

The data included in the present report were recorded at various research stations located on different soil types, i.e. Fundulea - medium leached chernozem containing 3.5% humus and 36% clay; Livada - podzolized soil containing 1.8% humus and 21.4% clay; Oradea - brown podzolized soil containing 2.25% humus and 38.41% clay; Secuieni - brown-reddish forest soil containing 2.8% humus and 21% clay; - Podu Iloaiei - leached chernozem containing 3.90% humus and 38.2% clay. At all locations, the trials were conducted according to a unitary programme, using the Latin square method with four replications and plots with a surface area of 25 m^2. In each station, Romanian hybrids released in the respective area were cultivated. During the vegetative period the effectiveness of the herbicides on the control of weeds was recorded; grain yields were estimated at harvesting.

RESULTS

A survey of the observations carried out for a longer time period showed that in maize crops the most frequent are the annual weeds, among which the following are more widely distributed; Sinapis arvensis, Setaria glauca, Setaria viridis, Echinochloa crus-galli, Amaranthus spp.,Chenopodium album, Polygonum spp. As compared with these latter, the perennial weeds are less frequent. The species Cirsium arvense and Convolvulus arvensis are present in most areas; Sonchus spp., Equisetum spp. and Agropyron repens occur in some areas.

The numerous studies conducted between 1960-1975 and summarised in table 1 demonstrate that atrazine showed the highest effectiveness in the control of annual mono and dicotyledonous weeds, this resulting in the highest yields of grain maize (85-110% of control).

Cyanazine and linuron were less effective as compared with atrazine and, consequently, the grain yields were lower than those obtained in atrazine-treated plots.

The herbicides containing alachlor, butylate and EPTC + antidote were highly effective in the control of annual monocotyledons (Setaria spp., E. crus-galli, Digitaria sanguinalis); the same herbicides were however, poorly effective in the control of such dicotyledons as S. arvensis, Raphanus raphanistrum, Chenopodium spp., and Thlaspi arvense etc. and for this reason the yields were constantly lower than in the atrazine-treated plots.

As a result of the negative characteristics of atrazine - its long persistance which gives rise to difficulties in crop rotation and the multiplication of some perennial weeds, in particular S. halepense during the last 9 years - attempts were made to mix atrazine with different "anti-graminaceous" herbicides with a view to achieving an effective control of mono- and dicotyledonous weeds. The results obtained in recent years (1977-1979) demonstrate the possibility of the integrated control of weeds in maize crops.

The results obtained on chernozem soils are presented in table 2.

On medium leached chernozem at Fundulea, S. arvensis was the prevalent species, followed by Setaria spp. E. crus-galli, Amaranthus spp., T. arvense, C. arvense and S. halepense. Under these conditions, atrazine was highly effective mainly during the seasons when C. arvense and S. halepense were absent. Due to the severe infestation with S. arvensis the control recorded in the plots receiving only alachlor or EPTC + antidote was poor, and therefore, the grain yields were low. An effective control of the mono- and dicotyledonous weeds was obtained in the plots treated with the herbicide mixtures alachlor + atrazine or EPTC + antidote + atrazine. Yields of maize grain were closely correlated with the rates of herbicide used.

Table 1

The effectiveness of several herbicides applied singly in maize crops in different areas of Romania

Herbicides	Rate kg a.i./ha	EWRS scores for annual weeds		Maize grain yields %
		Monocotyledons	dicotyledons	
Control hoed 3 times	-	1.0	1.0	100
atrazine	2.5	3.0	2.0	30-70
atrazine	5.0	2.0	1.0	85-110
cyanazine	2.5	5.0	3.0	30-50
cyanazine	5.0	4.0	2.5	50-60
linuron	2.5	4.0	3.0	40-55
linuron	5.0	3.0	2.0	60-70
alachlor	2.4	3.0	7.0	30-40
alachlor	4.8	1.5	5.0	40-55
butylate	4.3	2.0	7.0	30-40
butylate	5.7	1.5	5.0	40-55
EPTC + antidote	4.3	2.0	6.0	40-60
EPTC + antidote	5.7	1.0	4.0	60-70

Table 2

The effectiveness of different herbicides applied singly and as mixtures in the control of weeds and on the yields of maize grain

Herbicides	Rate kg a.i./ha	EWRS scores for: maize	EWRS scores for: weeds	Maize grain yields kg/ha	%
Fundulea - non-irrigated crop 1977-1979					
Control I hoed 3 times	-	1.0	1.0	6041	100
Control II not hoed	-	1.0	9.0	2145	36
atrazine	5.0	1.0	2.5	6992	115
alachlor	3.8	1.0	5.5	5836	97
EPTC + antidote	5.7	1.0	5.0	5755	95
alachlor + atrazine	1.4 + 1.5	1.0	4.7	5512	91
alachlor + atrazine	1.9 + 2.0	1.0	3.7	6044	100
alachlor + atrazine	2.4 + 2.5	1.0	3.0	7040	116
EPTC + antidote + atrazine	2.1 + 1.5	1.0	4.5	5945	98
EPTC + antidote + atrazine	2.8 + 2.0	1.0	3.5	6559	109
EPTC + antidote + atrazine	3.6 + 2.5	1.0	3.0	6880	114
			LSD 5%	1475	
			1%	2400	
			0.1%	3097	
Podu Iloaiei - irrigated crop 1977-1979					
Control I hoed 3 times	-	1.0	1.0	8473	100
Control II not hoed	-	1.0	9.0	3570	42
atrazine	3.0	1.0	3.0	7026	83
atrazine	5.0	1.0	1.5	8386	99
EPTC + antidote	4.3	1.0	4.5	6506	77
EPTC + antidote	5.7	1.0	3.0	7083	83
EPTC + antidote + atrazine	2.1 + 1.5	1.0	2.5	7556	89
EPTC + antidote + atrazine	2.8 + 2.0	1.0	2.0	8003	94
EPTC + antidote + atrazine	3.6 + 2.5	1.0	1.5	8300	98
			LSD 5%	985	
			1%	1283	
			0.1%	1680	

At Podu Iloaiei, the highest effectiveness and, likewise, the highest grain yields were obtained in the plots receiving atrazine at 5 kg ai/ha or EPTC + antidote in sequence with atrazine (3.6 + 2.5 kg a.i./ha). In the plots receiving only EPTC + antidote, the effectiveness and the grain yields, respectively, were lower due to the dicotyledonous weeds (Sinapis spp. and Raphanus spp.) which were not controlled.

Both at Fundulea and Podu Iloaiei the natural weed infestation was very high; in an average over 3 years grain yields were diminshed by 58-64% or 4,903 kg/ha, respectively.

On the brown and brown podzolized soils at Oradea, Secuieni and Livada, the monocotyledons Setaria spp. and E. crus-galli were prevalent. Of the dicotyledons, C. album, Polygonum spp. Anagalis arvensis, Soleranthus annuus, R. raphanistrum Amaranthus retroflexùs were the most frequent; the perennial weeds were represented by C. arvense, S. arvensis, Rubus caesius and Equisetum arvense. The effectiveness of the herbicides used in these trials was also determined by the ratio between species. The results obtained on the brown podzolized soils at Oradea and Secuieni are given in table 3.

Table 3

The effectiveness of weed control and effect on grain yield of herbicides applied singly or as mixtures to maize grown on soils at the Research Stations Oradea and Secuieni (averages for 1978-1979

Herbicides*	Rate kg a.i./ha	EWRS scores for: maize	EWRS scores for: weeds	grain yields kg/ha	grain yields %
Control I hoed 3 times	-	1.0	1.0	7113	100
Control II not hoed	-	1.0	9.0	973	14
atrazine	3.0	1.0	1.8	6040	85
atrazine	5.0	1.0	1.5	6648	93
EPTC + antidote	2.8	1.0	2.2	5855	82
EPTC + antidote	5.7	1.0	1.8	6420	90
EPTC + antidote + atrazine	2.1 + 2.0	1.0	1.8	6120	86
EPTC + antidote + atrazine	2.8 + 2.5	1.0	1.7	6360	89
EPTC + antidote + atrazine	3.6 + 3.0	1.0	1.2	6820	96
EPTC + antidote + 2,4-D + dicamba	4.3 + 0.7 + 0.1	1.0	2.0	6535	92
			LSD 5%	635 kg	
			1%	862 kg	
			0.1%	1162 kg	

* The treatments receiving herbicides were not hoed during the growing period

At both research stations, in an average over 2 years, the best control of mono- and dicotyledonous weeds was obtained in the treatments where atrazine was applied singly at 3 and 5 kg a.i./ha. Where EPTC + antidote alone was used the effectiveness of the control was relatively high since, as mentioned, the prevalent weeds were the monocotyledons. Consequently, in these cases the maize yields were high too, being close to those recorded in the control plot which was hoed 3 times. Since many EPTC - resistant dicotyledonous species are present in these soils, the application of herbicides containing EPTC and atrazine appears promising. With these treatments, the maize yields were close to those obtained with atrazine. Good results were also obtained in the treatment receiving pre-sowing applications of EPTC + antidote applied singly and post-emergence treatments with 2,4-D + dicamba.

On the brown podzolised forest soil at Livada, the annual monocotyledons were prevalent, amongst which Setaria spp. and E. crus-galli were present every year. Of the dicotyledons, the following species were more frequent: R. raphanistrum S. annuus. A. arvense, Polygonum spp. The perennial species were less frequent

(A. repens, S. arvensis, C. arvense and E. arvense), and for this reason the adverse effects on the yields were not apparent. Table 4 includes the average results obtained over 3 years.

Table 4

The effectiveness in the control of weeds and effect on grain yields of the herbicides applied singly or as mixtures to maize grown on brown podzolized soils at Livada (averages for 1977-1979)

Herbicides*	Rate kg a.i./ha	EWRS scores for: maize	EWRS scores for: weeds	Yields grain maize kg/ha	Yields grain maize %
Control I hoed 3 times	-	1.0	1.0	5577	100
Control II not hoed	-	1.0	9.0	1464	26
atrazine	3.0	1.0	1.6	3689	66
atrazine	5.0	1.0	1.5	6067	107
EPTC + antidote	4.3	1.0	3.5	5555	100
EPTC + antidote	5.7	1.0	2.3	5665	102
EPTC + antidote + atrazine	2.1 + 1.5	1.0	1.4	4976	89
EPTC + antidote + atrazine	2.8 + 2.0	1.0	1.3	6171	111
EPTC + antidote + atrazine	3.6 + 2.5	1.0	1.4	6218	111
EPTC + antidote + 2,4-D + dicamba	4.3 + 0.7 + 0.1	1.0	1.5	6751	121
			LSD 5%	1346 kg	
			1%	1780 kg	
			0.1%	2300 kg	

* The plots receiving herbicides were not hoed.

As a result of the high degree of weed control achieved with herbicide mixtures containing EPTC + antidote + atrazine, mean yields of maize over 3 years ranged between 4,976 and 6,218 kg/ha and were virtually equal to those obtained in the plots treated with atrazine at 5 kg a.i./ha. Similarly, an effective control of mono-and dicotyledons was also obtained in the plots receiving pre-sowing applications with EPTC + antidote and post-emergence applications with 2,4-D + dicamba. The mean grain yields over 3 years were 6,751 kg/ha.

The results obtained with single and associated herbicides over a 9 year testing period allowed us to develop several models of integrated weed control programmes:-

Model	Characteristic of the infestation with prevailing weeds	Herbicides needed	Rate kg a.i./ha
A. Single cropping for 3-5 years			
No. 1.	Annual mono- and dicotyledonous weeds	atrazine, simazine	2.0-6.0
No. 2.	Annual mono- and dicotyledonous weeds and perennial dicotyledonous weeds	atrazine, 2,4-D 2,4-D + dicamba	2.0-6.0 0.6-1.5 0.6 + 0.1
No. 3.	Annual and perennial mono- and dicotyledonous weeds, including Sorghum halepense	atrazine 2,4-D 2,4-D + dicamba glyphosate	2.0-6.0 0.5-1.6 0.6 + 0.1 2.8-3.6

Note Atrazine rates vary with the humus content of the soil. Atrazine is applied either in autumn or spring up to maize planting and is incorporated in the soil at depths of 6-10 cm. The herbicides containing 2,4-D and dicamba are applied as post-emergence treatments at the 3-6 leaf stage of maize. Glyphosate is applied as a pre-harvest treatment in earlier maturing hybrids, when S. halepense plants are still green.

Model	Characteristic of the infestation with prevailing weeds	Herbicides Needed	Rate kg a.i./ha
B. After maize grown in the single-cropping system and treated with atrazine			
No.4.	Annual and perennial mono- and dicotyledonous weed	alachlor 2.4-D + dicamba	2.4-4.8 0.6 + 0.1
No.5.	ditto	metalachlor 2,4-D + dicamba	2.0-5.0 0.6 + 0.1
No.6.	ditto	butylate 2,4-D + dicamba	3.6-8.6 0.6 + 0.1
No.7.	ditto	EPTC + antidote 2,4-D + dicamba	3.6-7.2 0.6 + 0.1
Note: The herbicides containing alachlor, metalachlor, butylate, EPTC + antidote are applied as pre-sowing treatments and are incorporated in the soil at 5-10 cm, while 2,4-D + dicamba are applied as post-emergence treatments, when maize is in the 3-6 leaf stage.			
C. Maize grown in rotation with other crops			
No.8.	Annual mono- and dicotyledonous weeds	atrazine alachlor	1.0-3.0 1.9-3.8
No.9.	ditto	atrazine metalachlor	1.0-3.0 1.0-3.0
No.10.	ditto	atrazine + cyanazine	1.0-3.0 1.5-3.0
No.11.	ditto	atrazine butylate	1.0-3.0 2.5-4.6
No.12	ditto	atrazine + EPTC + antidote	1.0-3.0 2.5-4.3
No.13. No.18.	Annual and perennial dicotylendonous weeds: _Circium_ spp. _Sonchus_ spp. _Convolvulus_ spp.	The same herbicides as under nos.8-12, but with additional post-emergence applications with 2,4-D + dicamba	0.6 + 0.1
No.19 No.24.	Annual and perennial weeds, including _Sorghum halepense_ and _Agropyron repens_	The same herbicides as under Nos 4-13 and glyphosate	2.0-3.6

The herbicides specified under nos 8-12 are applied as pre-sowing tank-mixtures and are incorporated into the soil to 5-10 cm depth. 2,4-D + dicamba are applied as post emergence treatments when maize plants are in the 3-6 leaf stage.

Glyphosate is applied after the preceding crop is harvested when _Sorghum halepense_ plants are 40-80 cm high.

It is of course, possible to develop other integrated control methods with the herbicides available now. These models are adequate for maize crops grown on tilled soil. For the cultivation of maize on non-tilled soil other models are developed involving mainly the use of non-volatile herbicides, among which paraquat is virtually indispensable.

DISCUSSION

Of the herbicides tested in Romania between 1960 and 1979, different non-volatile and volatile herbicides such as those containing atrazine, alachlor, metalachlor, cyanazine, butylate + EPTC + antidote, 2,4-D, dicamba and glyphosate can be used in the integrated control of annual and perennial weeds.

In the development of a model of integrated weed control, the following basic elements should be considered:

a) The characteristic of the infestation with annual and perennial weed species.
b) The activity range of each herbicide.
c) The optimum rates depending on the type of soil.
d) The status of maize in the crop rotation.

References

AMON, H. and HERI, W. (1979) Weed control in European maize growing. In Ciba Geigy Agrochemicals Maize, Basle, pp. 46-50

BEHRENS, R. (1979) Weed control in US maize. In Ciba Geigy Agrochemicals Maize, Basle, pp. 38-45

CRAFTS, A.S. (1975) Modern weed control. Berkeley, University of California Press, pp. 440

FRYER, J.D. and MATSUNAKA (Eds) (1979) Integrated control of weeds. University of Tokyo Press, pp.261

KASASSIAN, L. (1971) Weed control in the tropics. Leonard Hill, London pp.xi-307

KLINGMAN, G.C. and ASHTON, F.M. (1975) Weed science principles and practices. John Wiley, New York, pp. viii-431

LYUBENOV, J. (1970) Spravocinik po herbitidite. Zemizdat, Sofia, pp 269

SARPE, N. (1965) Excluderea prășitului la porumb prin aplicarea rațională a atrazinului. Revista Gospodariilor Agricole de Stat Bucuresti, (3), pp. 9-13

SARPE, N., CIORLAUS, AT., GHINEA, L. (1976) Erbicidele - principii și practica combaterii buruienilor, Editura Ceres, Bucuresti, pp. 361

SARPE, N. (1979) Weed control in maize in Rumania. In Ciba-Geigy Agrochemicals Maize, Basle, 51-54

VOEVODIN, A.V. (Ed.) (1964) Gherbițidî-sbornik statei, Izdatelstvo "Kolos", Leningrad, pp. 317.

NOTES

ECONOMIC WEED CONTROL IN TOP FRUIT AND STRAWBERRIES

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Summary Removal of weeds from top fruit orchards, and the grass strips under modern planting and training methods, show very clearly the economical benefits, which as the demand for better size and better quality fruit increased, will become more important. There is a wide choice of herbicides that can be used, but in order to cover the broad spectrum of weeds that are present, herbicide mixtures are usually preferred. The choice of herbicides is based on the weeds present, costs of the chemicals, and the ease of application. The cost is only important in relation to alternative chemicals, as the benefits from herbicides far exceed the costs of the treatments and applications.

With strawberries the economical benefits are even greater, providing damage to the crop can be avoided. In the selection of these herbicides, safety, therefore, plays an important consideration together with reliability and efficiency of weed control. Application techniques are also important as the correct application of the recommended dose has a great influence on efficiency of weed control and incidence of damage to the plants.

TOP FRUIT

Experimental evidence and commercial experience in every fruit growing area of the world has clearly shown the adverse effect of weed competition. Removal of this competition either by cultivation or herbicides has resulted in increased growth. Where the tree training techniques have exploited the new growth the result has been an increased yield, fruit size and quality. There have been a few situations where the type of pruning has nullified the advantages of extra growth so that there has been no benefit in terms of yield. In general, however, under modern pruning systems extra growth can be turned into increased yields and financial returns.

APPLE

Grass in Orchards

At the end of the First World War there was a marked increase in the use of grass in orchards as opposed to cultivations. This was very largely brought about by the advent of gang-mowers which were developed for the air strips in the War. Farmers found that the management of the orchards was much easier where there was a sward, compared with cultivations which gave problems associated with mud and ease of travel with wheeled vehicles. The type of pruning prevalent in those days was spur pruning which meant that the majority of the new growth was cut off so the reduction in growth caused by the grass did not show. Experiments at East Malling Research Station clearly demonstrated that there was far better growth under clean cultivations as opposed to grassing down, but the former did not result in better yields.

In the late 50's and early 60's there was a development of efficient herbicides for the control of weeds in orchards together with changes in tree training systems and management. Under these conditions the increased growth did result in better yields. Experiments at Efford Horticultural Station in orchards planted in 1963/64 quickly showed that there were large benefits to be gained by eliminating grass from the orchards completely, with much earlier and heavier yields. Experiments in Ireland, Long Ashton Research Station and East Malling Research Station have confirmed these results. It is very clear that weed competition results in substantially lower financial return to the farm.

Economics The total production and overhead costs for dessert apples is approximately six hundred pounds per acre, of which approximately half are the annual growing costs. The cost of weed control is less than one-tenth of the growing costs. The financial benefits, however, where there have been increased yields and increased fruit size, can be expressed in terms of hundreds of pounds per acre. Early trials at Efford Horticultural Station, comparing grass with cultivated soil, showed that over the five year period from grassing down in 1964, the accumulated yield from the cultivated plots was seven hundred bushels per acre more than similar trees in grass. The gross return from Cox on the cultivated area was six hundred and thirty nine pounds per acre, compared with three hundred pounds per acre on grass. The calculations are based on the calculated weight per plot and on the market returns of the period November to December.

Labour Utilisation The reduction of the size of the grass strip offers some benefits in increasing the yield and saving grass-cutting time, but experimental evidence shows that the maximum benefits are only obtained from overall herbicide treatment.

Complete removal of the weeds within the orchards releases labour during critical growing periods and saves tractor wear and fuel. Effective man management could enable the farmer to grow an alternative crop such as strawberries without increasing his permanent labour and in this way show an indirect financial benefit from the use of overall herbicides in addition to those already mentioned.

Application Problems. Reluctance on the part of growers to go across to overall herbicides has been associated to a certain extent with application problems. The utilisation of the teejet for side application, or the field jet, has given much more efficient control by enabling the grower to apply his herbicides safely. By using the Spraying Systems field jet KLC50 for overall application, relatively low application rates per hectare can be achieved: in the region of two or three hundred litres, whilst still applying a grass herbicide spray which is relatively free from drift. The nozzles are also simple and do away with the need for a boom, so applications can be made quickly, at about six to eight kilometres per hour.

Timing Applying the herbicides when the weeds are relatively small very important, as at this stage the herbicides are all much more effective. The use of the Spraying Systems nozzles with low drift risk enables the farmers to spray under most conditions; to be able to do so relatively quickly and the advent of these nozzles has greatly improved the efficiency of weed control, particularly because the weeds are being controlled at at vulnerable stage.

Cocktails With the varied weed spectrum present in orchards there is no single herbicide which will control the whole range of weeds. Most farms have adopted cocktail mixtures as this enables them with single applications to control the whole range of weeds. These are usually mixtures of aminotriazole, hormones, ie 2,4-D, MCPA, dichlorprop and mecoprop, and residuals such as simazine and diuron. These cocktails, which have been in general use for over ten years, are now used on a very large proportion of the acreage. There have been problems with resistant weeds developing and alternative chemicals have been used, such as glyphosate, particularly where Dactylis glomerata (cocksfoot), Lolium perenne (perennial rye grass) and sometimes Poa annua (annual meadow-grass) have given problems. The presence of a grass strip does make weed control much more difficult in orchards as this gives a source from which cultivations can spread both the stoloniferous and rhizomatous type of weeds and a source of seeds continually being blown onto the herbicide strips. The doctrine of overall herbicides results in more effective weed control and after a period of two years an actual decrease in the total cost of weed control in orchards can be achieved.

PEARS

There is far less experimental evidence on the benefits of weed control in pear crops, but commercially the majority of orchards are either treated overall with herbicides or a few orchards are still cultivated, and there is a steady decline in the number of orchards which are grassed down. Most farmers believe that grass is competitive, particularly for moisture, and results in poorer fruit size and smaller crops.

The selection of herbicides are usually the same as that used for the apple orchards, although greater care is usually taken as pears are more sensitive to herbicide damage and there are a few herbicides which can be used in apples but not pears.

STONE FRUITS

The amount of weed control by the use of herbicides in stone fruits is very much more limited as, in general, these crops are much more sensitive to damage, particularly from residual chemicals. The benefits, however, can be equally important and although there is very little experimental evidence, commercial experience would indicate more regular crops of better-sized fruit. Weed control is being successfully achieved on a number of farms using low doses of simazine not exceeding 560 grams active ingredient per hectare and repeating this treatment twice or sometimes three times a year. Very often this is used in conjunction with propyzamide again at low doses of 560 to 841 grames a.i. per hectare. The control of weeds already established is usually achieved by the use of aminotriazole or paraquat.

STRAWBERRIES

The control of weeds in strawberries is much more difficult than in top fruit because the crop plant is much more closely related in size and habit to the weeds than is the case with tree fruits. The importance of weed control, however, is much greater with strawberries, in fact, it could be said that the profitability of strawberries is directly related to yield and in the majority of situations the level of cropping is directly related to the efficiency of weed control. The only exceptions are where there is a particularly aggressive pathogen present such as red core, or the soil management has been particularly poor. Economically, there is no question that weeds must be controlled and controlled effectively. The most effective way of doing this is by the use of herbicides, but it does mean a constant appraisal of the situation and adjustment of the dose and type of herbicide that is used. Over the last few years a much greater range of herbicides has become available and it is particularly fortunate that there seems to be a relationship between the safety of herbicides on sugar beet and safety on strawberries. Thus the strawberry grower has clearly benefited from the herbicide developed for sugar beet.

The most widely used herbicide is still simazine which is very effective and economical. There are, however, problems with newly-planted strawberries in particular, where it is difficult to find the right dose which will effectively control the weeds and not damage the strawberry plants. One method of alleviating this problem has been to use charcoal dips as developed by Dr D W Robinson in the 60's in Northern Ireland. This is used quite extensively but it is a dirty operation and most growers would prefer to avoid if at all possible. The damage that simazine causes seems to be associated with the period very shortly after application and linked with heavy rainfall, which could also occur even with the alternative chemicals such as lenacil mixtures. The use of herbicide mixtures is helping to improve the weeds controlled.At the same time the safety to the strawberry crop, with the lower doses of particular chemicals with complementary weed spectrums, is providing a distinct advantage. The advent of propachlor chlorthal-dimethyl mixture on newly planted strawberries is offering safe and effective weed control at a very reasonable cost, with the added advantage that the recommendation is backed by the chemical manufacturers. It can, however, be relatively short lived in its efficiency, particularly in warm moist-conditions and requires a second application, or an alternative herbicide treatment, six to eight weeks after planting.

Commercially, a number of growers are using low doses of simazine at 140 to 420 grams a.i. per hectare, mixed with same dose of propyzamide. This has given a very effective control of annual weeds for a period of two months, but it is not recommended by the manufacturers. Risk of damage to strawberries is very much reduced on established plants and during the months of August to January. Under these conditions the herbicide doses can be increased giving a much more prolonged life and mixtures of propyzamide and simazine at 420 gramms ai per hectare each would give effective weed control for four to five months. An application after harvest and a repeat application at Christmas can give effective weed control for the whole year.

Problem weeds The perennial weeds are basically the main problem weeds in strawbrries and it is essential to chemically fallow the land before planting strawberries to get rid of the pernicious weeds such as *Agropyron repens* (common couch), *Cirsium arvense* (thistle), *Convolvulus arvense* (bindweed) and *Rumex obtusifolius*. The emergence of 3,6-dichloropicolinic acid for the control of *C. arvense* is a major step forward. *C. arvense* are becoming a major problem particularly where the strawberries were following the grubbing of orchards, and even where farmers kept the land free of weeds for two years prior to planting.

Experience in 1980 over a large area has shown the effective control of *C. arvense* can be obtained with 3,6-dichloropicolinic acid. There have been a few instances of slight damage but this has been far less than the damage created to the crop by *C. arvense*.

One of the major problems still seems to be the control of grass weeds, particularly *A. repens*. The use of propyzamide commercially has not generally been satisfactory, and there have been numerous occasions where propyzamide has not controlled *A. repens*. At the same time this has resulted in damage to the strawberry plants. The experience with alloxydim-sodium so far would appear to indicate variable results. Applications in 1980, gave an initial control of *A.repens* which was followed by regeneration, and even two or three applications have failed to give complete control in the one season. There was, however, no sign of any damage to the strawberry plants.

Convolvulus arvense can be a major problem in strawberries, and the newly effective control is that developed by Dr. J. G. Davison of the Weed Research Organization with applications of 2,4-D. This does result in distortion of the strawberry shoots and can be very worrying both for the adviser and for the farm. The plants, however, do appear to recover and any adverse effect is certainly less than the damage created by the Convolvulus arvense. There have, however, been occasions where standard doses have been exceeded and damage has occurred and resulted in even death of the plants. It would be advantageous to have a safer material.

Application Failure to get effective weed control and damage to the strawberry plant is often associated with inefficient application. Many of the spray machines are old and badly maintained and often there can be problems with overlap where the boom width does not match up to the planting distance of the strawberries. Even where care has been taken to calibrate the individual nozzles, problems have arisen where fan jets are used; the width of the fans can vary considerably and tests can show discrepancies of as much as fifty per cent in the volume of water applied over the width of the boom, due simply to this problem.

This can also be aggravated by incorrect setting of the height of the boom resulting in failure to control weeds in some rows and damage to the strawberry plants in others. There is a great need for more commercial use of measuring devices to ensure that the right application rates are maintained, together with a critical examiniation of the best type of nozzle that should be used.

References

ATKINSON, D. and HOLLOWAY, R.I.C. (1976) Weed competiton and the performance of established apple trees. Proceedings 1976 British Crop Protection Conference Weeds

ROBINSON, D.W. (1974) Some long term effects of the non-cultivation methods of soil management on temperate fruit crops. Proceedings of the XIXth International Congress, Warsaw, 3, 79-91

ROGERS, W.S., RAPTOPOULOS, T.H. and GREENHAM, D.W.P. (1948) Cover crops for fruit plantations IV. Long term leys and permanent swards. Journal of Horticultural Science, 24, 228-269

GUNN, E. (1967) The management of young trees at Efford. Efford Experimental Horticultural Station Annual Report 1967, 19-22

GUNN, E. (1965) Feeding and its effect in grass and arable orchards, Commercial Grower, 20 August 1965

NOTES

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ADVANCES IN CHEMICAL WEED CONTROL IN THE TROPICS AND SUBTROPICS AS AN INTEGRATED PART OF CROP PROTECTION

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Summary Use of herbicides in the tropics and subtropics cannot be considered as an established crop production technique. This is particularly so in the case of food crops on small farms. The factors which encouraged the technique in the industrialized developed world do not apply in the developing countries. New motivations must be defined, and inter-disciplinary research projects will have to supply the data, which will permit pinpointing of technological priorities to which to apply the limited financial resources available. Transfer of herbicide technology is pointless unless other production factors are employed to the best advantage.

INTRODUCTION

My subject is a very broad one, from the viewpoint of its geographical range, the climatic variations, and the socio-economic concepts which it encompasses. I have involuntary found myself making generalizations at the risk of inadequately reviewing the many diverse and special situations involved. My conclusions are directed to those developing countries which are in a particularly critical situation regarding their food supplies.

USE OF HERBICIDES

In a recent Gifap-compilation (1980), the distribution of plant protection chemicals between the developed and developing market economies is shown as follows:

	Developed World	Developing World
Herbicides	80 %	20 %
Insecticides	60 %	40 %
Fungicides	85 %	15 %
Total	75 %	25 %

These figures demonstrate the situation in 1979/80. The part of herbicides applied in the developing world is confined to few crops, mainly cotton, rice and sugarcane in Latin America. The predominant number of small farms of Latin America, Africa and Asia (apart from Japan) use an insignificant quantity of herbicides.

Our own company's estimates (Table 1) cover a longer period, and allow us to perceive certain trends, despite the shortcomings of such compilations. These data do not take into account the many positive examples of successful use of herbicides in a few countries and regions, where major efforts have been made and favourable conditions prevail. I have selected three crops of worldwide distribution, including sugarcane, a crop which is grown under unique agricultural conditions.

Table 1

Herbicide Use
(Treated area in % of total)

Rice	1971	1979
Central/South America (excl. Argentina, Chile)	9	53
Africa (excl. South Africa)	0.5	6
Asia (excl. Japan, Korea, PRC*, Burma, Cambodia, Taiwan)	1.5	6
Maize	**1972**	**1979**
Central America	10	25 (Central and South America combined)
South America	25	
Africa/Asia (excl. PRC*, South Africa)	2	11
USA	85	88
Sugarcane	**1972**	**1979**
Central America	45	90
Asia (Far East) (excl. PRC*)	6	10
Africa (excl. South Africa)	44	50

*People's Republic of China

Herbicide use in rice has become established in Latin America, but neither in Africa, nor in the developing countries of Asia.

Maize is a most important crop in small-scale farming. Usually the yield remains on the farm; the sale of surplus grain is seldom possible, i.e. no cash results from this crop so far, whereas in the industrialized world maize is a primary cash crop.

Sugarcane production is mainly in the hands of large sugar companies, which dispose of sufficient funds. That is to say, where production and markets are in balance, money is available, and modern technology is applicable.

Along with this low use of herbicides, expressed as percent of treated area, there is also the desire, or rather compulsion, to use the cheapest herbicides, which, as a matter of fact, give unsatisfactory results due to their unsuitable spectra of weed control and cause disappointment. Despite of these rather unsatisfactory applications of modern technology, many efforts to increase the yield of food crops in developing countries by various technological improvements had been undertaken. What is the outcome?

In Table 2, a survey of actual yields for rice, maize and sugarcane demonstrates that the yields in the developing countries are still very low, as compared with those of the developed market economies. Also the conclusion can be drawn that the relative improvements are marginal and/or not reaching the relative growth of the population during the past decade. In addition, the very sensitive increase of tractors was of little help for reaching reasonable yields. Considering all these facts, I risk to draw the following conclusions:

Table 2

Total Yield and Increase in total production of selected crops

	Total yield, 1978 t/ha			Increases in % since 1971 Total Production				
	RICE	MAIZE	SUGARCANE	RICE	MAIZE	SUGARCANE	Population	Tractors
Developed Market economies	5.8	5.0	80.0	10	42	20	7	15.5
Developing Market economies	1.6	1.3	54	25	11	35	23	70
- Africa (excl. South Africa)	1.4	1.0	54	18	15	23	24	32
- Latin America	1.7	1.5	57	23	5	31	24	39
- Near East	3.7	2.6	81	9	33	106	25	--
- Far East (excl. Japan)	1.8	1.1	50	26	15	42	22	121

FAO-Yearbook (1979)

- the measures taken have not yielded in the expected success
- there is doubt whether the efforts for improvement have been applied in an optimized and coordinated way
- the increase of tractors - it might not be very high in absolute figures for some countries - is not reflected in yields.

As a whole, the efforts made did not change substantially the obviously inadequate production technology.

These statements refer in first line to the important food crop rice and maize. Considerable local improvements had been possible for sugarcane, with the increasing interest in sugarcane as an energy plant.

STATUS OF CHEMICAL WEED CONTROL - AS A PRODUCTION FACTOR

If we assume that the technological efforts of recent times did not materialize in the necessary yield improvements, we should define the rationale of the failures. Going with the objective of the day - chemical weed control - my personal opinion of modern herbicide technology is that it is not established in the developing countries, and, further, that the use of herbicides as a generally accepted component of production methods, will not increase, unless special, new developments transform the picture. Knowledge of weed science and of herbicide use are and will not be converted into practice, despite the fact that more and more weed scientists are active in the "third-world" countries, scientists who have a solid training in American and European research institutes behind them.

This somewhat hard statement that modern weed science and herbicide-technology alone, as they are practiced in developed countries successfully, will not lead to substantial increases in food production in small-scale farming systems has its rationale in the fact that we need an integrated procedure of development, taking into account economic, social and all technological aspects of crop production. Further, weed control in future improved systems of tropical small farming is much more influenced by the given agronomic environment than it is in other production areas of the world.

Development of Herbicide Technology.
The availability of herbicides and the development of a scientific basis in weed biology and herbicide use are closely related with the development of the agricultural economy of the industrial countries in the temperate zone. As can be seen in Table 3, the percentage of population in agriculture is the most important factor which has influenced development of weed control technology, weed science and herbicide use.

Table 3
Proportion of the Population in Agriculture (%)

	1969	1978
Developed Market economies	13	9
- USA-Canada	4	2.7
- Western Europe	15	7.0
- Australia/New Zealand	8.7	6.8
Developing Market economies	65	60
- Africa	75	70
- Latin America	41	35
- Near East	62	55
- Far East (excl. Japan)	68	63

FAO-Yearbook (1979)

In the industrialised world the governing motivation for the known successful development of herbicide technology is:

saving labour as the scarcest and most expensive factor, and increasing productivity of labour and all other production factors.

This governing motivation has influenced the development of herbicide technology, weed research and crop production technique in "developed agriculture" to their present high standard.

How can we expect that the highly-developed herbicide technology of the industrialized world can be transferred to the developing world which does not have the same motivation pattern? The basic factors which determine the success or failure of this technology are exactly contrary in the case of herbicide use in the developing market economies:
- high percentage of population in agriculture
- no competition with highly-paid employment outside agriculture
- little capital investment to be paid off
- low development of alternative employment etc.

Weed control as a crop production factor. We all agree that weed control - whether manual or chemical - is one of the predominant crop production measures. Weed control is inter-related to:

- Rotational systems
- Soil cultivation techniques
- Planting time
- Crop spacing and density
- Fertilization
- Water availability (irrigation)
- Microclimate
- Occurrence of pests and diseases
- Maturity and harvesting time
- Harvesting technique
- Quality of the product

Changing weed control practice from traditional towards chemical control must therefore have a particularly sensitive and diverse impact on the whole crop production procedure. These sensitive influences are not yet sufficiently understood in the tropics and subtropics. We see so many isolated activities with only linear observation of weed control effects and crop safety. But herbicide technology - as it has developed in the industrialized world - must be further developed and applied, not necessarily from the aspect of labour saving as in the industrialized environment. Other motivations and new definitions of profitability need to be formulated:

- Yield increase per surface unit
- Increase of cultivated surface per capita
- Weed control in new rotational and cropping systems
- Weed control in soil conservation programmes
- Weed control as a factor in water conservation programmes
- And (only at a later stage) increase of labour productivity.

This means that any definition of a "need" for chemical weed control must be adapted according to the above-mentioned major motivating factors. But in this context we have to take into account all the other technology sectors involved:

- tractors
- soil cultivation equipment
- seeders
- quality seed
- fertilizers
- insecticides
- fungicides
- harvesting machines
- transport and storage

NEED FOR INTERDISCIPLINARY APPROACHES

The question is how and how much of this investment demanding parts of developed technology may be supported by a given production system. Each technology supplier tends to develop and support only those technologies for which he can capture a substantial part of the available money and market influence. The analogous situation is to be seen also in the scientific world: Weed science and weed research too have become a highly specialized branch of the whole. Weed scientists, too, tend to be pleased to see development of interest in weed science and even to see the use of modern control practices. Although we postulate interdisciplinary research and integrated approaches (here in Brighton as elsewhere,) weed scientists talk to weed scientists. Weed research has become monodisciplinary. In addition, scientists of the Third World are trained in this specialized environment and people concerned with technical aid are also very often working towards a restricted technology. No scientifically sound model is available which tells us, or tells the policy-maker in the developing world, or the individual farmers, how to use their limited money best, or what priority is to be adopted in a given situation. No integrated development concepts are known to me which help in setting technological priorities neither at the initiation phase - nor in the latter stages - of an agricultural situation with some 50 % or more of the population active or living in the rural environment. I mean, concepts using so called intermediate and appropriate technology.

Insufficient research data are available to show whether, for example, it is more advantageous, in terms of yield response, money and energy input to use high quality seed and control weeds chemically, rather than to use fertilizers, insecticides and/or fungicides. At an early stage in development, we have to chose between these kinds of alternatives, e.g.:

herbicides	versus	N-fertilizer
herbicides	versus	high quality seed
herbicides	versus	insecticides
herbicides	versus	fungicides
fungicides	versus	insecticides

Very little is known about the complex interdependence of these factors. This means that we have to consider multidisciplinary, multifactorial field research in the tropical/subtropical environment even more than anywhere else.

As an example, data of the kind which have been produced by DeDatta (1969), (Table 4), and Appleby et al (1976), (Table 4a), need to be developed for many more complex situations, to serve as a part to be integrated into decision making models. These figures show that interdependence between N-fertilization and herbicides is considerable. This kind of knowledge is missing from areas in which money is short, and where the priorities have to be set as a first measure.

Table 4

Effect of nitrogen level and weed competition on the grain yield of rice

Amount of nitrogen (kg N/ha)	Type of weeds	Weed weight t/ha	Yield of rice t/ha
0	grasses only	1.27	4.4
60	grasses only	2.32	4.0
120	grasses only	2.85	5.5
0	grasses + broadleaves	1.50	4.1
60	grasses + broadleaves	3.26	3.1
120	grasses + broadleaves	5.73	3.5
0	none; clean-weeded	0	4.5
60	none; clean-weeded	0	5.3
120	none; clean-weeded	0	6.6

DeDatta et al (1969)

In DeDatta's trial Monochoria was the predominant "broadleave" species, which apparently is a particular N-consumer.

Table 4a

Grain yields of a wheat at three nitrogen levels and four ryegrass densities

1 9 7 1

N level kg / ha	Ryegrass density plants m2	Wheat grain yield kg/ha	Grain yield reduction %
56	1	3.070	0
	12	2.680	12.7
	62	2.070	32.6
	114	1.920	37.5
112	0	3.570	0
	13	3.380	5.3
	45	2.300	35.6
	118	2.000	44.0
168	1	3.450	0
	14	3.260	5.5
	52	2.183	36.7
	84	1.720	50.1

Appleby, A.P. et al (1976)

CHEMICAL WEED CONTROL - ADDITIONAL MOTIVATIONS

In addition, in tropical and subtropical agriculture, there are two main factors which, for a developing economy, are the most important justification for the use of herbicides:

1. Erosion prevention
2. Water conservation

These factors must be built into any model of technological priorities. This means in practice that, in any weed research concept for these regions, these factors must be emphasised, since they determine the long-term maintenance of soil fertility. It also means that weed research in these regions, similarly to that in Europe at the beginning, must primarily be oriented to agronomy, i.e. to crop production.

Lal's (1976), (Table 5) results from IITA (International Institute of Tropical Agriculture, Nigeria) show what levels erosion and run-off can reach in the wet tropics. The classical methods involving deep cultivation are obsolete. The use of herbicides is indicated here, with the highest priority, under conditions where mechanical working of soil inevitably causes erosion. Therefore, special attention has to be given to other techniques of weed or vegetation elimination than burning and deep plowing. Money for chemical weed control needs to be used primarily for the crop establishment phase in order to prepare a reasonably clean seedbed without soil cultivation, and to facilitate germination and seedling development without early competition. If long lasting or season long weed control would absorb additional money-input, this then would need a careful balancing of such expenses for top fertilization, fungicides or/and insecticides applications.

Table 5
No-till effects on soil and water loss
(during 4 months under maize)

Slope %	Soil losses (t/ha) no-tillage	plowed	Runoff (mm) no-tillage	plowed
1	0.03	1.2	11.4	55
10	0.08	4.4	20.3	52.4
15	0.14	23.6	21.0	89.9

Lal, R. (1976)

But before no-till or minimum till agronomy can successfully be taken into consideration many other important technology components need to be available:

- Seeding machinery urgently needs improvement, since, on small farms, it must work without tractor power, or without powerful tractors. New machines must sow the seeds through a dead or living plant mulch into more or less solid soil layers. The rotary-injection principle of seeding, developed by R. Wijewardene at IITA (International Institute of Tropical Agriculture, Nigeria), could provide a basis for a break-through in this branch of technology.
- Small machines for the economical use of fertilizers, by placement, for minimum-/no-till agriculture must also be developed.
- European and American experience shows that the desired decrease in soil cultivation intensity can lead to shifts in weed flora and the complexes of pests and diseases. These findings must be re-investigated in tropical agriculture too.
- Application machinery for herbicides is comparatively well developed, even for small-scale farmers.

These brief evaluations of different unsolved problems demonstrate that many new and peculiar problems exist for weed research in the tropics and subtropics to work on:

1. Crop - Weed - Competition in mixed cropping situations
2. Selectivity in mixed cropping
3. Establishment of weed free cover crops
4. Maintenance of cover crops after crop harvest
5. Yield contribution of cover crops under various exposure and density regimes / N-equivalency
6. Weed emergence and weed suppression under leguminous cover crops

7. Yield results with varying weed control levels below perfection
8. Yield effect of varying weed control-fertilizer levels, each below optimum
9. Active nutrient partition between crops and important weed species
10. Sensitivity investigation of all other production factors and technologies with respect to
    - yield increase
    - labour utilization intensity during cropping season.

In order to improve yields over the pure subsistance level, and so to progressively feed the non-agricultural population, this kind of research is urgently needed. Experts from the highly developed agricultural environment must understand the background and usefulness of agronomic practices different from theirs like mixed cropping, mulching, cover crops, etc. We cannot simply discredit the traditional methods of farmers in the developing countries and do everything to implant directly our efficient, high level of technology.

Improvements have to start with the improvement and perfecting of existing systems, not by introducing highly sophisticated/prestigious technology at whatever cost.

We, as Weed Scientists, have to accept the fact that the first step to the improvement of crop production is not, in each and every case, chemical weed control. The priorities need to be worked out jointly with our colleagues from all the disciplines involved in crop production, including agricultural economists and rural sociologists.

Weed control technologies in the developing world, for the time being, have to be chosen primarily to increase yield, to maintain soil fertility, and not necessarily to save labour, especially where unemployment is high and where trade and industries are non-existent.

If we are looking for advances in chemical weed control in the tropics, we have to consider them as a part of a production system for food crops. We have to try to achieve our goal in close cooperation with all other disciplines involved. Additional motivations are to be developed for chemical weed control.

Weed Research has to play a leading role in an interdisciplinary and integrated approach since this discipline has not only the task to protect from losses by weeds, but has also the task to develop methods permitting reasonable engagement of available manpower resources, decrease the energy-input to a minimum and secure the fertility of soil.

References

ANONYM (1980): Gifap Bulletin (April/May), No. 2, Vol. 6

ANONYM (1979): FAO-Yearbook

DeDATTA, S.K., MOOMAW, J.C., and BANTILAN, R.T. (1969): Effects of varietal type, method of planting and nitrogen level and competition between rice and weeds. 2nd Asian Pacific Weed Control Interchange.

LAL, R. (1976): Soil Erosion Problems on an Alfisol in Western Nigeria and their control. IITA Monograph No. 1.

APPLEBY, A.P., OLSON, P.D., and COLBERT, D.R. (1976): Winter Wheat Yield Reduction from Interference by Italian Ryegrass. Agronomy Journal, May-June, Vol. 68, 463-466.