Development, research and application of crushing drums to prevent volunteer potatoes

by E.N.C. Meijer - J. Frederiks
IMAG Netherlands.

Summary

Ever since I973 the Institute of Agricultural Engineering (IMAG) Wageningen Netherlands did research on the crushing of harvest losses between rotary drums. Crushing drums were first used in practice by the van der Meer brothers, potato growers in the south western part of the Netherlands. In close co-operation with Machine Manufacturers de Jonge, the makers of AMAG potato harvesters, a crusher for research was developed which is now (I978) at a stage to come into production. In the meantime the same principal is introduced in a harvester: crusher combination. As harvesters can not be transferred into combined harvester crushers there will be room for both. In a research programme different conceptions of the crushing machines were build starting with a very simple one web and ending with a tripe web. The latter gave more sieving and thus a heigher capacity.
Power requirements hardly exceeded the expectations and never exceeded 50 h.p. (36,8 kW). Experiments with drums with different sizes (4I on 26 cm diameter) did not show much difference. Although the smaller sized drums are cheaper, and the crushing performance does not differ from the bigger once the latter are chosen in the first practical operated machines. The crushing results vary considerably depending on the soil type and the circumstances at the time of crushing.
On light sandy soils crushing effects of 90% were quite normal. On heavier soils the effect is somewhat lower.
The machine equiped with narrow spaced webs is also suitable for crushing flower bulb fields which suffer from ground keepers too.

Introduction

During the last decades potato volunteers became one of the most awkward weeds in the Netherlands. A number of reasons can be mentioned, the high rate of machanisation being the most important followed by a number of very mild winters. The use of harvesters equipped with wide webs cause a lot of losses sometimes exceeding 300.000 tubers per hectare. If one realizes that a number of 30.000 tubers per hectare is planted and ten times this number is left in the ground he fully recognizes the problem.
Not only from a point of view of weed but also from a point of view of a healthy potato growing, this problem should be solved as soon as possible.
The van der Meer brothers who are large potato growers in the south-western part of the country were the first to use crushing drums. The Institute of Agricultural Engineering took over this idea by developing in close co-operation

with machine manufacturers de Jonge (makers of AMAC harvesters) a crushing machine. The research started in I973 and is still being continued.
Successively a number of crushers were build, with one exception all of them in close co-operation with machine manufacturers de Jonge.
As far as the research is concerned, the Institute of Agricultural Engineering did research into the fundamental value of the crushing drums and the evaluation of a separate crusher whereas the Research station of arable farming (PAGV) researched the combination of harvesting and crushing.

Research

The first crusher was built from a 3-row beet harvester. The beet lifters were replaced by potato shares over the full width (I.50 m). A single web with a clearance of I2mm replaced the beet cleaning web and at the end where normally the side delivery elevator is fitted, two crushing drums, one metre fiftly wide, were installed.
As it is impossible to separate soil and potatoes completely, the crushing drums have to crush a mixture of the two. Under very light sandy soil condition it happens that potatoes only are to be crushed; this is more troublesome than having some soil or leaf remains in the material to be crushed. The diameter of the crushing drums was 4Icm from the beginning although research was carried out with 25cm drums.
One of the drums was installed on a fixed place whereas the other could move about IOcm to enable stones and other obstacles to pass without ruining the drums.
The crushing drums in the first concept were hydraulically driven. The drums rotated with different circumferential speed towards each other.
Different drum speeds were advantageous to obtain the selfcleaning effect of the drums as scrapers wear very quickly and require extra power. Later on in the research, drums were equally driven which meant a more direct and positive grip on the material. Under moist conditions scrapers on both drums become a necessity.
The performance of the crushing drums could be examined better in a separate crusher than in a harvester fitted with a crusher. This does not mean that we exclude the possibilities of a combination but in the early stage of the research we could work only with a very simple machine. Later on, it turned out that separate crushing under certain conditions had strengths which will be discussed later on.
The first experiences were positive from a point of view of crushing. The pick-up part of the machine had many trouble with the more or less loose soil varying to compact in the wheeltracks and wide spread plants.
A non driven but turning torpedo and a finger-wheel of a hayrake brought some improvement but the problem was not solved.
In a later design a toothed rotary cultivator above the digging shares was installed which gave a mor3 direct transport from the shares into the direction of the first web. During the I977 harvesting period we expected a capacity increase from this alteration. Although the machine was very evenly fed it seemed to be impossible to exceed a speed of 3.6km per hour.

During this research many measurements into the power requirements were done starting under light conditions in silt soils and ending under more or less heavy conditions in a peat soil. Figures of these measurements are presented in table I. The number of volunteers, mainly from undamaged tubers, was established in the spring of I978.

Table I. Power requirements of the pick-up crushing machine on heavy peat soil.

Number of rev. of the drums rev./min	p.t.o. power rquirement in KW	number of volunteers/m^2 in May I978
290 - 650	I6,2 - I7,2	0,8
290 - 520	I6,2 - I9,I	0,8
540 - 360	I3,2 - 25,0	I,I
900 - 500	I8,4 - 24,3	I,8
900 - 900	20,6 - 22,8	0,8

Although this part of the country (North east) had a fair number of frost days to kill groundkeepers, five volunteer plants per square metre were counted on the 'not-crushed' plots.

On light soil in the south west part of the country we found figures as mentioned in table 2.

Table 2. Power requirements on light silt soils

Number of rev. of the drums in rev/min	lifting shares	lifting rod	p.t.o. power requirements	number of volunteers/m^2
400 - 260	+	-	II,7 KW	0,II
400 - 260	-	+	26,4 KW	0,II
400 - 260	+	-	I7,6 KW	0.II

in combination with toothed rotary cultivator

On the 'hot-crushed' plots a number of 0,3 per/m^2 were found. This low number of volunteers must be looked upon as a combination of crushing, desinfection of the soil and frost. The latter having less influence in this part of the country.

As one can conclude, the power requirement were not very high. The total power requirement (in the table only the p.t.o. requirements are presented) are about 40 KW as a maximum. A 44 KW (60 h.p.) tractor preferably with fourwheel drive can do the job in most cases.

At the end of the I977 harvesting season a lot of information was gathered about the power requirements and it was disappointing that no adjustment could be found to raise the capacity.
As soon as the speed was increased the machine was unable to sieve out the soil which resulted in overloading the crushing drums and in no time a blockage of the machine resulted.
To raise the sieving capacity, the total sieving surface, the shaking attachment and the number of steps in the sieving line had to be enlarged. This meant a total new concept consisting of three webs each I.50m wide and each with a shaking attachment. At the end of the last web a rotating axle with blades was installed which should throw the remaining mixture of dirt, leaves and potatoes through a rack of rods as a last link in the sieving line.
The machine as described was taken in research at the beginning of the I978 seed potato harvesting period. It was immediately stated that the sieving capacity confirmed the expectations and travelling speeds up to 5 Km/h were possible. The research with this new conception will be continued throughout the harvesting season. A first impression of the power requirements show somewhat higher figures. A 90 hp (66 kW) tractor can pull and drive this machine.

Table 3. Power requirements of the I978 pick-up crushing machine on light silt soils

Number of rev. of the drums	rev./min of axel with blades at the end of the last web.	p.t.o. power requirements 4 km/h	5 km/h	6,5 km/h
360 - 810	330	20(31)	17(17)	11(14)
360 - 650	330	18(22)	11(14)	15(14)
650 - 360	600	27(27)	20(19)	15(17)
650 - 650	600	30(30)	25(37)	19(21)

between brackets are figures on light cultivated soil whereas the other figures were obtained on soil left by the harvester and lorries.

Table 4 presents some figures of the 1978 concept potato crusher.

plot	number of tubers/hectare or parts of tubers that probably gives a plant
not crushed	254.00
crushed (without any soil cultivation after harvesting)	9.100
crushed (with a shallow soil cultivation after harvesting)	7.500

Discussion:

The figures presented in the different tables show very clearly the positive effect of crushing. In tables 1 and 2 the capacity of the machine was very low. However, during a number of demonstrations in the fall of 1977 practice showed some interest in this way of crushing. The altered machine has not been confronted with severe circumstances. The first impression however is promissing.
After this combination of harvesters and crushers in flowerbulbs and potatoes, a separate crusher can become an important help in the fight against ground keepers.

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MODIFIED HARVESTERS TO PREVENT WEED POTATOES

L.M. Lumkes and H.E.M.M. Vervaet
Research Station for Arable Farming and Field Production of Vegetables (PAGV),
1 Edelhertweg, 8219 PH Lelystad, the Netherlands.
J.T. Andringa,
Advisory Service for Machinery and Labour (CLA),
12 Mansholtlaan, 6708 PA Wageningen, the Netherlands.

Summary In the frame of a multidisciplinairy working group the opportunity of reducing potato harvest losses and destroying inevitable losses is in study. An important part of these losses is caused by errors in the growing systems (row distance e.g.) or is a result of the use of too big tractor tyres, wrong track distances and uncareful harvesting techniques. It is possible to reduce the level of losses considerably.
Several types of modifications and adaption of potato harvesters to control harvest losses are being developed, others are in progress. The best principle is collecting and crushing of all inevitable losses. Using this system a few manufacturers have gained successes. In the Netherlands, controlling potential volunteer potatoes in this way starts to be common. Crushed ground keeper tubers are far enough destroyed for hardly producing volunteer plants anymore.

Resumé Dans le cadre d'un group de travail sont l"Organisation de la Recherche Scientifique Appliquée (TNO), plusieurs disciplines étudient la possibilité de diminuer les pertes de la récolte de pommes de terre et de détruire les pertes inévitables. Les pertes sont causées en grande partie par des fautes dans la culture ou sont l'effet de l'utilisation de pneus de tracteur qui sont trop grands, d'un écartement de voie faux. Plusieurs types de modifications et d'adaptions ont été attachées aux arrâcheuses de pommes de terre. Le meilleur principe est le rassemblement et la destruction de toutes les pertes inévitables. Avec ce principe quelques fabricants ont beaucoup de succès et on l'applique de plus en plus à l'échelon pratique. Les pommes de terre qui ont été détruites ne peuvent pas se lever l'année prochaine.

INTRODUCTION

About 25% of the arable crop rotation are potatoes. In some important starch potato growing regions this even goes up to 50% of the crop rotation.
Research on the control of volunteer potatoes has been carried out in the Netherlands since 1970 as a cooperative subject of a multidisciplinairy working group (Lumkes 1973). Weed potatoes make it hard to get a healthy potato crop (phytophthora and virus diseases) and to keep a healthy soil (cyst nematodes).
Several opportunities to control volunteer potatoes are studied. Killing of ground keepers by frost and or by soil tillage as a natural way of controlling is not effective enough under Dutch conditions.
This paper reports research about controlling harvest losses at its source. Basically this is initiated by some Dutch farmers and contractors.

They adapted or modified their harvesters to reduce the level of harvest losses (normally up to 500 000 tubers per ha) and to destroy the inevitable losses.
In 1977 several types of solutions to control potato harvest losses in the harvesting machine were tested. All the machines involved are practical machines. Some of the modifications are designed by farmers, mostly however by the manufacturers.

METHODS AND MATERIALS

Each type of machine (modified or adapted) is tested several times during the harvesting season in 1977, mostly under different soil conditions. If possible, further modifications of the machine were carried out to get progress in the results. The final proposition for a well-known type of the trailer type double row potato harvester, delivering to carrier, is described and illustrated in Figure 1. In Figures 2 and 3 series of tests are summarized with each type of machine, as carried out in a rather permanent developing stage. The principles tested are also given in Figure 2 and 3.
Each test is started with an orientation about the crop in that specific field (yield, sizing) and a specification of all the technical aspects of the harvesting unit.
To discover when and where the tubers are being lost, winded plastic sails of 15 meters length and with a width of 1,75 meter were unrolled under the harvesting machine (Figure 1). The sail is winded on an axle, but not fixed to it. During the harvest work it is unrolled without stopping , the machine can continue while a measuring strip is available. Afterwards the axle of the sail is demounted from the machine to use it again (Lumkes et al, 1978).
So it is possible to determine the origin of the losses, the effect of the crushing unit and also the percentages of soil and potatoes passing the various parts of the machine.
As crushed tubers are considered only those tubers which are destructed in this way. As far as they are not ground to powder, the damaged ones are mostly killed afterwards by rotting and/or frost. Occasionally a damaged potato tuber may produce a volunteer plant. This however will be a small plant, easily to be killed mechanically, by crop concurrence, e.g.
The harvest losses studied by this method have a systematic character. It is clear that incidental losses cannot be analyzed by using the method described. Apart from the results in 1977 the effects in volunteer potato plants in 1978 and this also related to tillage method and crop, are studied.

RESULTS

The number of lost tubers is related with various aspects, such as rotation intensity (volunteer plants in seed potatoes), variety (with relatively small tubers), planting depth, row distance, ridging and foliage stripping (when unsuitable tyres are used), etc. If sufficient attention has been paid to all these aspects and if the digging unit of the harvester is set well the amount of losses is considerably decreased.
The principle of the potato harvester is that a mixture of about 90% soil and 10% potatoes is dug up (ridges about 600-800 cm^2 , yields of about 50 ton/ha). During the transport in the harvester the soil needs to be sift out by passing through sieves. To reduce harvest losses of small tubers the webs however only need to have small gabs. This has lead to compromises in sieving capacity and level of losses. If many small and big potatoes are lost while harvesting, then this is often caused by leaks elsewhere in the machine.
With an adapted potato harvester as described in Figure 1, on marine clay soil experiments were carried out during several years. The machine now has a collecting

web for harvest losses and a crushing unit. The sieving capacity of the main web is the same as in the original version. The underwebs run at a higher speed than the main web does, which thins the layer of soil and potato losses. This layer passes the crusher again at a higher speed (see also the technical description in Figure 1).
In Figure 2 the results of the tests with practical machines of a double row, trailer type potato harvester delivering to carrier (DK2-1976 and EK2-1977 type) are given. Basically these types are the same. The 1977 version has apart from other improvements steered wheels. In 1978 again a series of this Dutch machine is produced, based on the 1977 version.
The results in Figure 2 demonstrate that the level of losses on clay soils goes up to approx. 340.000 tubers/ha without collecting and crushing. Most of these tubers are small, but the losses caused by wrong methods (too big sized tractor wheels e.g. - 0 in Figure 2) are big tubers in general. Not all the tubers passing in the crushing unit are crushed (or crushed enough - T in Figure 2). Sometimes they pass with too much haulm, soil, stones, e.g. Thus uncrushed tubers are nearly always very small and not really dangerous. A crushing level of about 97% as reached in Figure 2 is acceptable.
The overall reduction in losses of about 85% is acceptable when the number of uncrushed tubers is less than 50.000 tubers/ha. According to experiences in the Netherlands 10-20% of these losses will germinate and produce a volunteer plant the next year.
As described in Figure 3, on sandy soils several types of modified harvesters are tested. This research is carried out on starch potatoes. The machines studied are single or double row types, all of the trailer type, delivering to carrier or into bulk hopper. Until now no self propelled machines, adapted or modified to control harvest losses, are in practical use.
The potato lifters are more or less radical changed, see Figure 3.
In general the losses on sandy soils are lower than on clay soils (Z in Figure 3). The losses caused by culture methods, tractor wheels, e.g. are however much higher (= 0 in Figure 3). A crusher or a collecting container under the weed mat of the harvester (system SB and P in Figure 3) does not help enough. Since this is a simple and cheap modification of a very common machine, it is better than doing nothing to control the losses.
Small main sieving webs (systems E2 and CG in Figure 3) reduce the sieving capacity under wet conditions too much. In the system CG a combination with a crusher under the weed mat is not yet enough effective neither (30% overall reduce of losses).
The described system S - a single row machine - and the system EK 2 are based on collecting the potential losses on special webs and then crushing them.
The system S is developed in 1977 and worked well in a series of machines in 1978.
Both in 1977 en 1978 the EK2 system showed the same good results on sandy soils as on clay soils.
On clay soils as on sandy soils, the effect of crushing potato harvest losses in number of volunteer plants, depends on the crushing intensity. All potential losses should pass the crushing unit. The 1978 survey on the fields in which in 1977 the functioning of the machines was analyzed, demonstrates that there is a very close correlation between the absence of volunteer plants in 1978 and a good crushing result in 1977.

DISCUSSION

As volunteer potatoes are a serious problem, several subjects are tested to control this weed. It needs no saying that an integrated control system, based on several measures, seems to provide the solution.
The source of the volunteer potato plant is the ground keeper tuber, left at the field at harvesting. Based on the research described, it seems to be possible to decrease the level of losses by making better use of the available techniques.
Partly the harvest losses are inevitable. These losses need to be collected and destroyed. Some types of the tested machines are well suited for this purpose.

However, this is an expensive investment because the price, compared to a standard machine lies 10-30% higher. Therefore the introduction starts slowly, which gives alternative control methods a chance. Basically the best solution is the control by destroying harvest losses.

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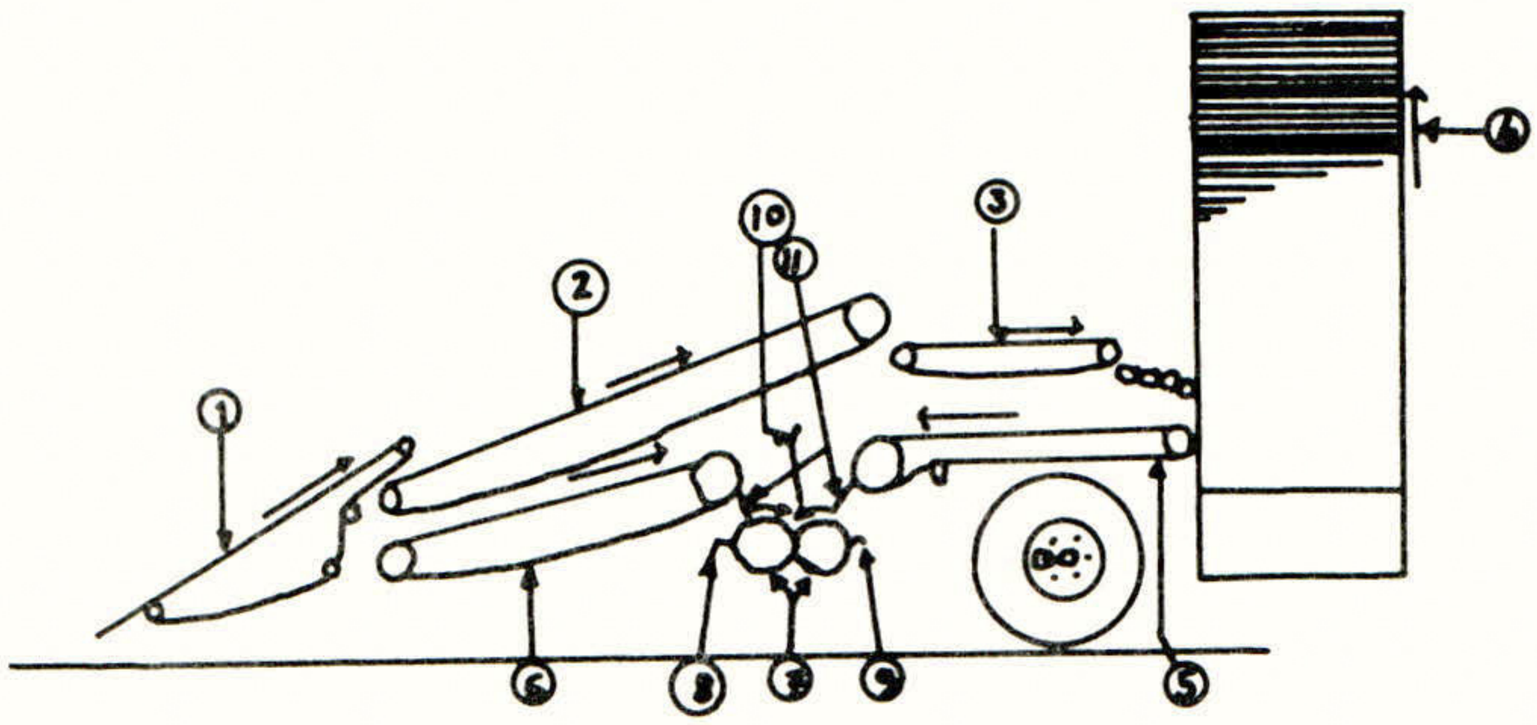

Figure 1.

Adapted potato harvester, system code EK2, as in use on marine clay soil.

Component number	Description	Function	Intervening space in the sieving web	Speed mm/sec
1	1st elevator web		18	1.11-1.8
2	2nd elevator web		25	1.19-1.72
3	3rd elevator web		22	± 1.11
4	4th elevator web	web delivering to carrier	17	0.69-0.77
5	under web with small gabs	collection of losses	13	1.47-2.42
6	under web with small gabs	collection of losses	13	1.36-2.03
7	crushing unit	crushing of losses		
8	1st crusher drum	crushing drum,diameter 40 cm, length 150 cm, rev./min 750		
9	2nd crusher drum	crushing drum, diameter 40 cm, length 150 cm, rev./min 750		
10	1st haulm roll	4 sets of opposite turning rolls		
11	2nd haulm roll	4 sets of opposite turning rolls		
12	last cleaner			

Figure 2 Adapted potato harvesters, tested 1977 (78) on marine clay soils.
Averages of repeated countings. Figures in number of tubers per hectare or in percentage

Principle of reducing/ destroying harvest losses		Control of leak losses; collecting of inevitable losses on special underwebs and crushing between rolling drums	
Code of the system		DK2, 1976-type	EK2, 1977-type
Losses without collecting and crushing	(=Z=U+O)	340.000	349.000
Losses caused by culture methods, tractor wheels (tyres) and the digging unit of the harvester	(=O)	56.000	54.000
Losses collected and offered to the crusher	(=U)	284.000	295.000
Tubers not crushed when passing the crusher	(=T)	18.000	7.000
Harvest losses when the collecting system and the crusher are used	(=R=O+T)	74.000	61.000
Crushing effect of the collecting and crushing unit	$(=\frac{U-T}{U} \times 100\%)$	94%	97%
Overall reduce in losses	$(=\frac{Z-R}{Z} \times 100\%)$	77%	83%

Figure 3. Adapted potato harvesters, tested 1977 (78) on sandy soils.
Avarage of repeated coutings. Figures in number of tubers per hectare or in percentages.

Principle of reducing/ destroying losses	Sieving web with 17 and 13 mm intervening space	Sieving web with removable in-between spikes (intervening space 9-15 mm) and crusher under weed mat	Crusher under weed mat	Collecting container under weed mat	Collecting of losses on underlying special sieving webs and crushing between small rolling drums with hook angle profile	Collecting of losses on underlying special sieving webs and crushing between big rolling drums
Code of the system	E2	CG	SB	P	S	EK2
Losses without collecting and crushing (=Z=U+O)		124.000	192.000	136.000	216.000	230.000
Losses caused by culture methods, tractor wheels (tyres) and the digging unit of the harvester (=O)	128.000	86.000	159.000	107.000	125.000	28.000
Losses collected and offered to the crusher (=U)		38.000	33.000	29.000 to the container	91.000	202.000
Tubers not crushed when passing the crusher (=T)		1.500	2.000	no crusher	4.000	5.000
Harvest losses when the collecting system and the crusher are used (=R=O+T)	no crusher 128.000	87.500	161.000	107.000	129.000	33.000
Crushing effect of the collecting an crushing unit $(= \frac{U-T}{U} \times 100\%)$	no crusher	96%	95%	no crusher	96%	97%
Overall reduce in losses $(= \frac{Z-R}{Z} \times 100\%)$	no crusher	30%	17%	24%	40% [1]	85%

[1] first experiments with prototype

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THE FARMERS NEEDS FOR HERBICIDE MIXTURES AND PROGRAMMES

C. J. Whittles

CJW Cereal Consultancy Services Ltd.,
1 School Lane, East Keal, Spilsby, Lincolnshire

Summary The advent of high input cereal production has necessitated the use of a programmed approach, not only for weeds, but for pests and disease control within the modern cereal crop and all arable crops.

This needs to be done with clear objectives in mind as to how it may be carried out and then the programmes formulated to give the most cost effective and efficient return on capital investment.

There are problem areas with persistency, resistant weeds, the necessity for sequential treatments and the use of multiple mixtures which are outside manufacturers recommendations.

Appropriate mixtures are suggested for each individual crop stage and the need for manufacturer and user participation in proving the efficiency of appropriate combinations, which would then be reported back to one another.

INTRODUCTION

The objective of this paper is to try and assess the requirements of the farmer in the present and in the near future for combined weed control and other crop protection programmes in commercial crops.

This is too wide a brief to be tackled in this session and all the examples used will be based on Winter cereals, as this is an area where major needs are being shown.

In the cereal crop, programming of inputs is becoming an increasingly important area and it is causing much confusion amongst farmers and advisers alike. It is no longer possible to look at weed, pest or disease problems in isolation, because many products are applied to crops as mixtures or sequential treatments, often with one or more herbicides being involved. This can also cause inter-related problems at a later stage because of different combinations of materials used.

In order to clarify the problems it is worthwhile looking at the basic principles involved in weed control in the cereal crop. All the evidence suggests that the maximum yield response from herbicide use is achieved by application before the crop has reached the end of

tillering stage. Thereafter, herbicide use is unlikely to result in substantial yield increases, but uncontrolled weeds can cause problems with harvesting and contamination of samples, particularly in a bad harvest. Therefore, it is important to aim at control of weeds at the earliest possible stage and to resort to clean up of subsequent problems as they occur.

THE OBJECTIVES OF WEED CONTROL

1. To increase crop yield and quality.

2. To minimise crop damage and competition from weeds.

3. To achieve a clean crop and ease harvesting.

4. To do the above as cost effectively as possible.

5. To achieve the above four without damage to the environment or to the crop and without undesirable residues of chemical.

FORMULATING PROGRAMMES

When formulating programmes, it is important to consider the various types of weed problems that are going to be present e.g. the grass weeds, including wild oats (Avena spp), the broad leaved weeds and the perennials.

The next consideration is the choice of herbicides which could be very diverse and the following factors need to be taken into account:

1. Whether residual herbicides are required.

2. The desired timing of application and whether application will be pre- or post-emergent (late Autumn up to the end of November, Winter from December to end of February or early Spring end of February, early March).

3. Whether sequential spraying to remove weeds resistant to early treatment or perennials and Spring germinating annuals weeds which develop at a later date will be required.

It then requires knowledge of other probable chemical usage i.e. insecticides, fungicides and growth regulators which may in turn influence the choice of appropriate materials for weed control.

Examples of typical weed problems and possible crop protection programmes which could be used:

1. Heavy soil growing continuous Winter cereals with a blackgrass/wild oat problem, cleavers, polygonums and late developing thistles.

   Cultivars being grown - Armada and Hobbit

   Typical programme for Armada would be:

   (a) Chlortoluron - pre-emergence

(b) Mecoprop at half dose to deal with early developing cleavers - late Autumn
(c) Mecoprop plus growth regulator and fungicide in the Spring
(d) Barban to remove late germinating Spring wild oats
(e) MCPA at growth stage 10.5 to control late thistles

The programme for Hobbit would be as for Armada but (a) chlortoluron - pre-emergence being substituted by isoproturon plus mecoprop at three-leaf stage post-emergence.

These programmes have some treatments outside recommendations i.e. the Winter application of Mecoprop at low dose and the very late application of MCPA to control thistles.

2. High organic matter soil, no blackgrass problem but a severe wild oat problem also high levels of broad leaved weeds, particularly hempnettle and the polygonums.

Cultivars being grown - Kinsman and Bouquet

The problem on this soil is that residual herbicides will not work efficiently, therefore either contact or hormone type herbicides will need to be used to keep the weeds under control.

Examples would be as follows:

(a) Ioxynil plus bromoxynil to remove broad leaved weeds plus half rate difenzoquat to remove early wild oats - early Winter.
(b) Hormone type weed killer (possibly in a formulated mix with one of the contacts e.g. ioxynil, bromoxynil, mecoprop combination) applied in the Spring with the growth regulator and the fungicide.
(c) Difenzoquat to deal with the later germinating wild oats at a subsequent stage.

3. Medium loam soil growing high levels of blackgrass and a normal broad leaved weed spectrum excluding cleavers and perennials.

Cultivars being grown - Winter Barley - Igri, and Winter Wheat - Maris Huntsman

Examples of a treatment in this situation for both cultivars would be isoproturon, either pre- or post emergence to control the entire problem. Post-emergence treatment might well be delayed until the Spring if weather conditions were bad when isoproturon would remove most of the broad leaved weeds and blackgrass, and no further weed control treatment would be necessary.

4. A light soil with minor annual meadow grass problems, major wild oat problem and low level broad leaved weed problem.

Cultivars being grown - Mardler and Hustler

In this situation the following could be used:

(a) Tri-allate incorporated into the seed bed, then over-sprayed with pre-emergence application of methabenz-thiazuron. This combination should then control all

the weeds until the Spring.

(b) There may then be need for a sequential application of a broad spectrum or even minor spectrum herbicide to clean up any broad leaved weeds.

(c) Sequential wild oat treatment with benzoylprop-ethyl if a major emergence of wild oats has taken place or the alternative would be to use barban or low dose difenzoquat.

All the above programmes assume that weather conditions are favourable to apply them, the crops go in the ground at the correct time and the land is fit for the spray machines to cover the ground.

When formulating these programmes, it is important to look at cost and by juggling the strong points of various chemicals, it is possible to halve the cost of chemicals. Conversely, the cost may be doubled by the wrong choice of chemical.

PROBLEMS INVOLVED WITH USING EARLY APPLICATIONS OF RESIDUALS AND OTHER CHEMICALS

1. The persistency

In an ideal world it would be the optimum solution to apply one chemical, pre-emergence which would control the entire weed problem throughout the growing season of the crop.

Unfortunately, there is no such chemical commercially available. Therefore, the concept of programmes has to be investigated and appropriate programmes utilised.

The residual chemicals e.g. chlortoluron, isoproturon, metoxuron, methabenzthiazuron, terbutryne will all control weeds to a certain level. They then depend upon crop competition to suppress any subsequent germination of seedlings and any re-growth of partially controlled weeds.

Their effectiveness can be greatly affected by time of application i.e. if applied pre-emergence to September drilled crops, then they may lose activity before the Spring flush of weeds emerges and sequential application may be needed.

In a poor growing season, particularly a wet season, these chemicals will break down within the soil rather faster than in a more average type of season and consequently, subsequent flushes of weeds can become a major problem in the crop and could greatly affect harvesting efficiency and perhaps create the need for sequential treatment.

Most of the Spring applied herbicides are of a contact or translocated nature and therefore have little residual activity.

2. Resistant weeds

With residual herbicides applied in the Autumn, the major resistant weed problem tends to be cleavers (Galium aparine) which can and does develop throughout the Winter and again in the Spring. With

increasing usage of residual herbicides in Winter crops, cleavers are becoming a greater problem, and need to be dealt with at the earliest stage to give efficient control.

Other problem weeds are volunteer potatoes, grasses, such as rye-grass (Lolium spp) from previous crops, and perennial weeds such as creeping thistle. Control of some of these weeds by chemicals is not possible because suitable products are not available e.g. to kill potatoes in a cereal crop.

Creeping thistle (after early applied Spring herbicides) tends to regrow and is becoming an increasing problem. Therefore, it is important to be able to control this weed late in the season when there is a possibility of not only complete control in that crop, but hopefully, of complete eradication.

3. Sequential sprays

In unfavourable weather conditions etc., residual herbicides tend to run out of steam in the Spring particularly if they are applied to early sown crops, pre-emergence, therefore, the necessity for sequential sprays in the Spring becomes that much more important. Provided you have got a good healthy crop which is competing well with the weeds, then a low dose rate of a specific or broad spectrum herbicide could well be used in the Spring and stop most of the weeds, but in a catchy season, where spraying is difficult and with a lot of rain about, then a higher dose, broad spectrum chemical e.g. an ioxynil, bromoxynil, mecoprop mixture may well be required, but again all these materials increase the cost of the programme.

INTEGRATED WEED PROGRAMMES WITHIN A FULLY INTEGRATED CROP

An example of a possible crop calendar for a September sown wheat on a soil which has a major weed problem:

(a) Sowing date - middle of September.
(b) Seed bed conditions - good, therefore pre-emergence residual herbicide applied.
(c) End of October - early growth of cleavers and disease development therefore requireing mecoprop plus a fungicide.
(d) Middle of November - after heavy rain, crop under stress requireing additional Nitrogen - Nitrogen applied.
(e) Middle of February - first Spring top dressing.
(f) Middle of March - sequential weed control required to remove remainder of over wintered cleavers and the early flush of cleavers, growth regulator needing to be incorporated plus fungicide to deal with foot rot diseases.
(g) Middle of April - second major Nitrogen phase.
(h) End of April - wild oat problem develops from Spring germinating wild oats requireing herbicide plus the second Spring disease treatment to control foliar diseases.

(i) Early June - next disease control phase, manganese deficiency developed plus early build up of aphids. Requirements - fungicide plus manganese sulphate plus aphicide.

(j) Early July - re-infection of aphids plus crop short of nutrient plus additional disease control requirement plus late growing thistles.
Remedy - foliar feed plus fungicide plus aphicide plus herbicide.

Most of the combinations used in this example are either one or two in some cases three way mixes, but in practise, it is quite conceivable that a mixture, as much as eight ways could be found e.g. the farmer who has a Spring weed problem plus requirement of growth regulator, fungicide and herbicide. An example of this may well be as follows:

CMPP + ioxynil + bromoxynil + chlormequat + carbendazim + manganese chealate + copper chealate + a foliar feed

When this complexity of mixture is needed, there is no manufacturer that I am aware of which will recommend it as a tank mix, but it happens in practise.

Most manufacturers are prepared to recommend one of their own products with one of somebody elses, but very few of them will recommend more than a two way mix and they are understandably cautious of three way mixes. When you get to the ridiculous stage of eight way mixes, then nobody wants to know!

This is an area where further work, within specific growth stages is needed. Examples are as follows:

<u>Winter period</u>

1. The use of paraquat with all the residual herbicides applied pre-emergent. This cannot be done at the moment with a lot of the residuals because of physical imcompatibility.

2. The use of mecoprop with residual herbicides applied post-emergence.

3. The possible requirements of mixing a residual herbicide, mecoprop and a fungicide in the Autumn.

4. The use of an aphicide with the post-emergence combinations.

5. The use of residual herbicides and wild oat herbicides post-emergent.

<u>Spring period</u>

1. The use of herbicide plus fungicide plus growth regulator. This is standard practise commercially although in most cases, outside manufacturers recommendations.

2. Then the thorny situation of chlormequat plus MBC (benomyl, carbendazim, thiophanate-methyl) followed by the wild oat treatment with benzoylprop-ethyl.

   The manufacturers recommendation is that carbendazim should be applied at growth stage 3-6 and followed by chlormequat plus benzoulprop-ethyl at a later date.

   Cropwise, the requirement is for Cycocel/MBC to be applied early

followed by the benzoylprop-ethyl, but this is outside manufacturers recommendation for the use of benzoylprop-ethyl!

There is now strong evidence being produced from field use, that the mixture of chlormequat plus MBC followed by benzoylprop-ethyl, in fact gives good results.

3. The use of residual blackgrass herbicides plus chlormequat plus MBC. This could well be an important need after a difficult Autumn and difficult Winter when it has been impossible to get the materials applied to the crop.

Early Summer (April onwards)

1. Wild oat killers (at growth stage 6) with chlormequat and a fungicide as a combination.

2. The use of foliar feeds plus insecticide, growth regulators or fungicide. There are now several mixtures which could be used in a cereal crop.

Fairly intensive work is needed within these mixture phases to avoid the problem of chemical failures because of the multiple mixtures which could have been used. There is also the problem of the impairing of biological efficiency where these combinations have been used or alternatively the increase of biological activity due to a multiple usage of any particular chemical.

Another problem which could occur in this phase, is that certain varieties may react to multiplicity of chemicals, whereas used individually, they are perfectly safe.

A further potential problem with residual chemicals, is the persistence of these materials within the soil and the desirability or even necessity to change products on a continual basis. This can well cause problems with climatic variations, in other words, very wet years or a series of dry years, which may well impair the breakdown and leeching of these chemicals from the soil. All these are problems which are going to continue.

With integrated programmes, timeliness of application of materials is most important, not only for cost effective use of the chemical but also for timely control of the problem. The use of aircraft, low ground pressure vehicles, wide boom sprayers or even (dare we say), ultra low volume usage of materials to enable fast, efficient use of product, all need to be investigated.

The priorities within this field, I feel, are in the mixture phase so that the farmer has a wide choice of approved products and manufacturer recommended mixtures so that he is not in the situation of taking his crop into his hands and risking an out of recommendation usage, which from the consultants and manufacturers point of view, is not desirable.

There is also a need for manufacturer and farmer participation in trying to assess the efficiency and ethicasy of some of these mixtures. There may well be a requirement at a higher level for this to actually take place in the future.

With the incredible number of combinations which could be dreamed up, it is important to pin-point the major areas, to have manufacturers laboratory tests for chemical and physical compatibility carried out, and then reporting back on mixtures that have been used successfully and more particularly, the combinations that have caused problems or have failed.

CONCLUSION

In the last five years, there has been a major revolution in the use of herbicides, insecticides and fungicides within the farming community. The need is carefully balanced programmes which are safe in every respect.

The farmer requires further coverage of mixtures which he can use with safety to meet specific problems as they occur on the farm. There are certain groups of weeds which are creating additional problems.

The climate and varietal problems tend to alter with the season and consequently put additional strains on the manufacturers to produce approved combinations which will control the problem with absolute safety.

There is a lot of work required by both the manufacturer and the farmer in assessing and getting approved the appropriate combinations which will then benefit the crop and ultimately all concerned.

This would need to be followed up by farmer usage and reporting back to manufacturers and the appropriate body in the Ministry where the combinations have been successful but particularly when problems have occurred, some form of bureau should be set up in conjunction with manufacturers, merchants, consultants and farmers to co-ordinate field results where non-recommended mixtures have been used.

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PRACTICAL PROBLEMS OF THE AGROCHEMICAL SUPPLIER

J.R. Metcalfe

Bartholomews (Chichester) Ltd., Chichester

For years the Distributor has fulfilled the role of merchant in holding and financing stocks of chemicals required by the local farming community, delivering these stocks onto farms and collecting the money. But, as always, roles never remain static and with the tremendous advance in the use of agrochemicals, the Distributor role has changed, as have the laws and rules governing the recommendations given and regulations for storage and transport of the product.

To start, I must outline the service I see the modern Agrochemical Distributor giving the farmer, the relationship with the manufacturer and the conflicts caused by new regulations and laws. These conflicts are arising mainly in the recommendations for on-farm tank mixes. Finally to put forward some ideas for clarifying the position so that we may serve agriculture in the best and most responsible way.

The Agrochemical Distributor is increasingly becoming the source of technical information to the farming community as he has a wider range of products to offer the customer than the manufacturers' representative, who is a specialist in his own Company's product. This change has occurred in the last 10 years with the higher use of chemicals in order to maximise yields and with the increasing range of chemicals used on the farms, which come from many different sources.

Inevitably if the Distributor is giving more advice, storing more products and delivering more, then some controls must be provided. These controls will be provided by BASIS (British Agrochemical Supply Industry Scheme), which is a voluntary scheme developed by all sides of the Agrochemical Industry to ensure that technical advice is from qualified personnel; also that storage and delivery is carried out in a safe responsible way to those who are directly concerned in handling the material and to the public at large.

Having looked at the technical requirements, I must now outline the responsibility we have to the manufacturers whose research produces the new products we sell and whose finances build the Plant that manufactures the chemicals. The millions of pounds spent on developing products must be recouped in the minimum time to ensure continued investment for new materials. The Agrochemical Distributor is the point of sale for the product therefore we must assist our suppliers to sell products. However, a Distributor must have a full range of products and these will inevitably be supplied by more than one manufacturer. Each supplier will test his own materials and carry out chemical and biological tests to see whether they are safe and effective.

Government control requires mixed chemicals to be cleared through the Pesticide Safety Precaution Scheme but physical compatibility and safety clearance through the PSPS Scheme are only the first stage for making recommendations for a tank mix. Evidence is also needed to show the mixture is safe for the crop and that the components are still effective against weeds, fungus diseases and insect pests. Why should a manufacturer clear his product as a mixture with a competitors material and bear the costs ? Rightly BASIS requires Distributors to sell only recommendations cleared through the PSPS Scheme.

Our farmer customers must be our main concern. They rely on us to recommend the right products to safeguard their crops. It must be remembered that we are net importers of food and must maximise our farmers yields as long as it is going to increase their profits. Higher yields will reduce imports and help the balance of payments. Also, our farmers must be competing with the same products available to them as their continental competitors. They already have enough handicaps from the Green Pound reducing their net incomes.

In modern farming the right advice inevitably means the mixing of chemicals in tank mixes, as Mr. Whittles has explained. We can only recommend those products cleared through the PSPS scheme and generally those are only mixtures of one manufacturers labels. What is more, many Ministry experimental farms and the WRO are writing up trial work of mixtures and sequential treatments that are not cleared for commercial use. This information is freely available to farmers who wish to be in the forefront and use the most advanced chemicals to maximise their production.

How many products are actually manufacturee by the name on the label ? How many sources of Chlormequat, BCM or even MCPA are there ? Should manufacturers still try to keep to the myth that they make all their own products, or should we be able to have a very simple elimination of many mixes not cleared through the PSPS scheme by manufacturers co-operating when they are all selling a product from one basic plant ?

Looking at our responsibilities to the farmer in law, the Sale of Goods Act has arrived without any clarification as to how it is applied in law to our farmer customers. Does it mean that if we sell a blight spray for control of blight in potatoes and we have a year such as we have just seen, that the supplier of the goods will be held responsible for the disease of the crop ? How can we provide our farmers with the best advice as a Distributor when we have a law that is likely to work against the interests of the industry ?

Is a technical adviser who is paid for his advice liable under the Sale of Goods Act or is the Distributor, who may only supply the goods, the person who bears the responsibility for products used ? Similarly, are ADAS involved with the performance of products recommended, or is it only the supplier ?

I have tried to outline the job that the Agrochemical Distributor is trying to do and the problems we are, or could, meet by advising non cleared recommendations of mixtures and sequential treatments to farmers. Who can help us regulate the position and clarify the law ? It must be those nearest the corridors of power and that must be the Ministry of Agriculture. What can they do ? Firstly, they should co-operate with manufacturers to see if they can produce a catalogue of products of the same manufacture and cross reference these to make a wider range of tank mixes that could automatically be cleared through the PSPS scheme for farmer usage.

Secondly, if the experimental farms make their trials available to farmers and encourage chemical mixtures, then they should be prepared to co-operate with manufacturers to obtain commercial clearance. It is irresponsible to advise the use of chemicals which should not be used by law.

When laws are made, such as the Sale of Goods Act, someone must know for whom and what they are meant to control. Who best to clarify the position of the Agrochemical Industry than the Ministry.

The farmers need tank mixed chemicals and sequential treatments to maximise yields. The Distributive Industry are trying to take a responsible position through the voluntary BASIS scheme. We need the manufacturers to co-operate with the Ministry to clarify the legal position and to speedily produce a list of chemically and biologically compatible products cleared through the PSPS scheme to safeguard British agriculture.

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THE MANUFACTURERS' ROLE IN MEETING THE FARMERS' NEEDS

H.P. Allen
Consultant, Hindhead, Surrey

Summary Economic pressures have compelled arable farmers in recent years to seek to optimise yields from their crops, using every weapon at their disposal. The days of 'low input', 'low output' farming have gone. Even the cereal grower who a few years ago would have been very happy to average 30 cwt. per acre for his Spring barley and 40 cwt. per acre for Winter wheat, is farming his cereals as potato and sugar-beet growers farmed their crops, ie. staking a high plant expense against a still higher planned reward. Hence the interest in the cereal growing systems of Professor Laloux and Dr. Braun, wheat clubs with a target of 4 tons per acre, tramlines, etc., etc. Advice for cereal men from U.K. and the continent differs in detail but common to all systems is the requirement for frequent inspection of the crop and a 'total' approach to the control of weeds, pests and diseases: a need for 'split' applications of fertilisers; and a recommendation to apply a growth regulator.

Inevitably, with a programme such as this, the question of tank mixes of chemicals must arise, eg. can an eyespot fungicide be applied with a hormone weedkiller, or a black grass chemical ? Can wild oat herbicides be tank-mixed with foliar fungicides ?, Can liquid fertilisers be mixed with pesticides ?, Can a *Rhynchosporium* fungicide be mixed with a hormone weedkiller ?

DISCUSSION

This whole question of tank mixes and sequential treatments has been the subject of papers at previous Crop Protection Conferences here, eg. Mr. Peter Scarr and Mr. P.J. Long at the 1976 Weed Conference. It has also been a major topic for discussion at the Herbicide Usage Reviews of 1976 and 1977, and will be discussed again this year (1978). Mr. Scarr (1976) drew attention to the pressure put upon farmers and growers to maintain the highest standards of 'crop cleanliness', not only because the consumer and the processor demand this standard, but because 'shortage of skilled labour and sophisticated machinery dictate the need for weed-free crops'. He went on to outline the unknown factors inherent in herbicide mixtures and even in sequential treatmemnts of herbicides derived from different manufacturers, often with no knowledge available as to whether or not such a practice would be safe. Mr. Scarr also expressed some doubt as to whether manufacturers give enough assistance to distributors in the way of advice about mixtures, and he also questioned whether official bodies were doing enough in this field.

Mr. Long stated that ' in the past manufacturers were not at all keen to be involved in advising about, hearing about, or even admitting the possibility of tank-mixing, so users stumbled along finding out the hard way, and even dragging industry along behind them .' He also pointed out that many farmers, though able to forecast their weed problems well before the event, nevertheless do not in many cases plan their chemical application and pre-crop cultivations to meet the forecast problems; he inferred that lack of such planning often led to the use of 'emergency' mixtures unencumbered with any knowledge of what might happen as a result and he prophesised that ill-effects arising from such unplanned action would lead to restrictive legislation which would make life difficult for all concerned. Finally, Mr. Long drew attention to the serious lack of information concerning pesticide mixtures as exemplified by the recommendation of B.C.P.C. Working Party on compatibility that 'there was no case (in 1975) for holding a symposium on the broad subject of compatability of pesticides due to lack of quantitative data'.

The situation has changed, to some extent, since 1975 in that at the 1977 Review of Herbicide Usage, reports collating field experience with pesticide mixtures were submitted by A.D.A.S.; N.F.U.; Departments of Agriculture for Scotland, and for N. Ireland; B.A.A.; U.K.A.S.T.A. and others, and those reports were summarised briefly by Mr. R.J. Makepiece (of A.C.A.S.). At that same review, Mr. P.J. Jones of A.C.A.S. drew attention to some of the difficulties inherent in recommending mixtures, and pointing to the need for a great deal of work before manufacturers can make recommendations for tank mixes based on information satisfactory to P.S.P.S. and A.C.A.S.

To summarise what has been written and said publicly on this subject it appears that:-

1) There is a great and widespread need (or desire ?) to apply tank mixes of herbicides with other herbicides and/or with fungicides and insecticides, also to apply sequential treatments.

2) There is inadequate knowledge of the practicability, efficacy and safety (to crop and consumer) of such mixtures and sequential treatments.

3) Manufacturers are reluctant to become deeply involved in the research and development work necessary to have specific mixtures cleared by P.S.P.S. and approved by A.C.A.S.

4) There is doubt as to whether official bodies take any initiative in easing the farmers' problems - indeed it is inferred that the only initiative displayed by such bodies is restrictive rather than supportive !

These statements require careful examination because, like all general statements, they incorporate a number of assumptions. That there is a need for mixtures of herbicides with other herbicides, with fungicides and with insecticides is incontestable. What is not so clear is which needs are top priority and must be met by tank-mixes. From the information that has been put together by different organisation, it is not possible to assemble a list of absolutely essential mixes. Put another way, it is not yet possible to distinguish clearly between 'need' and 'inclination'. Surely, we have reached the stage when major justifiable needs for mixtures have to be drawn-up crop by crop. For some crops such lists exist and much is known about mixtures, eg. onions and sugar beet; top fruit. For the cereal crop there is a most urgent requirement for such a list.

From the full lists of needs, priority requirement would have to be established, and the next step would be to investigate to what extent these priority needs can already be met within existing mixture recommendations. If this point could be reached, then at least the problems of meeting farmers' requests for tank mix recommendations would be reduced to manageable proportions !

So what is industry's role in meeting farmers' needs for advice and recommendations on the use of tank-mixes ? In times past, when technical advisers in industry were asked about compatibilities of their products with those of another manufacturer (ie. about compatibility information not on the labels of either manufacturer), if the information was not already available the advisers would suggest that the enquirer should mix the products in a bucket in the right dosage rate proportion and observe whether or not they were physically compatible. From that point on, any action would be taken at the enquirer's risk and that would be made very clear. The manufacturer would probably also invite the enquirer to weigh the risk of applying the tank-mix against the risk of crop failure were the mixed chemicals not applied - alternatively, sequential treatments of the two chemicals might have been recommended if time allowed this approach. Again, in times past, informal advice - even label recommendations at 'grower's risk' were quite common.

This informal approach is no longer possible because of current legislation. The law, as it now stands, demands that disclaimers (ie. warnings that in certain circumstances a chemical or a mixture of chemicals, might not be fully effective) must be 'reasonable', whatever that means ! In other words, current legislation is such that a grower's risk recommendation by a chemical manufacturer seems no longer to be a practical proposition.

It follows from this that recommendations by manufacturers concerning the use of mixtures of chemicals require the support of evidence of physical, chemical and biological compatibility, sometimes of toxicological safety. Currently, discussions are in progress between the Ministry of Agriculture, Fisheries and Food (MAFF) and the British Agrochemicals Association (BAA) on the question of clearance of tank-mixes under the Pesticides Safety Precautions Scheme (PSPS). I would like to quote from the MAFF's Draft Policy Statement, now under consideration by BAA. The underlining is mine !

" (1) Mixing of pesticide formulations should be carried out only in accordance with manufacturers' recommendations given on the product label, or any other instructions, written or verbal.

(2) Manufacturers should be encouraged to extend the range of tank-mix recommendations to cover those mixtures for which there is a justifiable need by farmers and growers. It is recognised that with so many products on the market there are thousands of potential permutations and it would be impossible to test and clear them all.

(3) The number of cleared mixes is increasing and the aim is gradually to clear all the most commonly needed combinations. To this end, manufacturers should be encouraged to carry out the tests necessary to show that the tank mix does not present any greater potential hazard than the individual products used singly. While the information required in support of notification must depend on the specific mixture under consideration, information on physical compatibility will be essential. "

The draft Statement goes on to summarise the MAFF's view on the general principles relating to compatibility statements in manufacturer's labels and literature. In particular, that trade names should be used wherever possible, that trade names belonging to another manufacturer should not be included on a label without that manufacturer's consent in writing, and that where the compatibility statement involves pesticides for which there are a large number of formulations available, the statement may refer to 'cleared formulations' of specifically stated active ingredients.

There is also a clause stating that where there is likelihood of farmers or growers using mixtures that are known to be unsuitable the labels may carry appropriate warnings. Another paragraph states that even when there is no potential safety problem from the use of a tank-mix there may be loss of efficacy and/or phytotoxicity. Accordingly, ACAS approval of such a mixture would require adequate evidence that such drawbacks are only minor.

I make no apology for quoting extensively from this Draft Policy Statement. Again, I must emphasise that at the time of writing this paper the Statement is only a draft - but it does indicate the size of the task which would be faced by the manufacturer even if only top priority needs are considered.

In order to present this paper in a representative way, I have had discussion with a number of agrochemical manufacturers and every person to whom I have spoken has made it clear that his particular Company neither could nor would devote time, money or resources to unstructured 'blue sky' testing of 'possible' chemical tank-mixes - the futility of such an approach must be obvious to all.

The inferences from my discussions are that there are obvious and specific instances where agrochemical manufacturers would involve themselves in compatibility studies with tank-mixes, eg. where the components of the mixture are properties of one manufacturer; where, say, a herbicide owned exclusively by one manufacturer poses certain problems when mixed with another herbicide or with another pesticide - but when the case for mixing the chemicals in question is very strong; or where a herbicide with a wide range of uses is in demand as a tank-mix component; and of course, where clear commercial advantage is likely to result from the ability to mix safely chemicals belonging to two (or three) manufacturers. Once again we arrive at this question of great and justifiable need !

I believe that, though a search through crop protection literature will reveal more gaps than answers about tank-mixes, the manufacturer has demonstrated his willingness to test mixtures of crop protection chemicals and indeed the Research Reports included in this Session bear some witness to this.

Messrs. Morris, Jones and Luckhurst of Shell point to the pressure from growers wishing to see integrated pest control programmes and to the need for clear co-operation between manufacturers - they are looking at mixtures of wild oat herbicides and foliar fungicides.

Messrs. Gilchrist and Lake, of Dow, reporting on trials with mixtures of 3,6-dichloropicolinic acid with post-emergence sugar-beet herbicides indicate improved weed control and some flexibility to reduce dose rate - as a result of using such mixtures. Similarly, Messrs. Wise and Farrent, of Elanco, report the results of their trials with mixtures of trifluralin and TCA for weed control in winter oilseed rape, indicating that weed control from this mixture proved superior to that from either herbicide used alone. Yet again, Messrs. Slater and Jones, of May and Baker, in reporting their work with tank mixes of Hydroxybenzonitrile/ mecoprop esters and Hydroxybenzonitrile/isoproturon salts with major wild oat herbicides, foliar fungicides and growth regulator formulations, state that their experiments are at least partially a response to the cri-de-couer from the B.C.P.C. Working Party on compatibility concerning lack of quantitative data about tank-mixes. These and many other trials are examples of work done partially in response to farmer pressure, but such recorded uses of mixtures are a 'drop in the ocean' compared with unofficial mixing on the farm, the extent of which can only be guessed.

Mr. Whittles and Mr. Metcalfe in their papers have stressed the desirability of manufacturers producing more information concerning tank-mixes. Mr. Metcalfe also suggests that it should be possible to reduce the list of 'duplicated' mixes not cleared through PSPS by manufacturers co-operating, together and with MAFF, when they are all selling a product from one basic plant, and that MAFF produce a library of products from different firms but of the same manufacturer. On the face of things, the proposition sounds very reasonable. Two points should be borne in mind however; first, that the chemical sold by a number of firms from one basic plant may take the form of several different formulations; and second, information lodged with PSPS and ACAS is confidential. I merely mention these points to demonstrate that the exercise might be rather more involved than Mr. Metcalfe implies.

I have formed the view that industry's role in meeting the needs of the farmers and growers concerning advice and recommendations about tank mixes will be constructive but reactive until and unless clear and justifiable need is established - which brings me back to my earlier point - the urgent requirement for the establishment of a list of priority needs, crop by crop - the work now required to establish 'mixture' recommendations could be of such detail that only for major needs will the necessary collaborative research be done. Mr. Whittles has certainly outlined a number of chemical tank mixes which would qualify for a short-list of major needs.

In the draft MAFF Statement alluded to earlier, reference is made to 'the tests necessary to show that the tank-mix does not present any greater potential hazard than the individual products used singly ', this implies toxicological research as well as field trials and manufacturers are well aware of the long lead time that now exists between petitioning and clearance - to add to this problem with a plethora of submissions for clearances of mixtures would be pointless. No - the manufacturer will respond to demands from farmers and merchants provided the need is great and established beyond doubt, also provided the list of such needs is reasonably short !

The outstanding point is - who will compile this list of priority needs ? In my own view, those bodies which have already furnished information on the field use of tank mixes, ie. those represented at the Annual Review of Herbicide Usage, are in the best position to provide such information. I believe that a questionnaire should be devised and circulated - by N.F.U. to farmers, by U.K.A.S.T.A. to merchants, by B.A.A. to manufacturers, with contributions from A.D.A.S. and from Department of Agriculture in Scotland and N.Ireland, also from the colleges there. Since a questionnaire would have to ask not only what combination of problems demand the application of tank mixes of pesticides but why a tank-mix is the only way of dealing with the matter - for instance, a mixed weed problem demanding a number of herbicides for its solution might be tackled be separate applications on 50 acres of cereals - but might require a one-application, mixed herbicide treatment on a farm growing 1,000 acres of cereals.

The replies to this questionnaire, after careful sifting and analysis, may hopefully give a clearer picture of major needs. The next thing would be to check against this list 'mixture' recommendations already available - then the needs still to be met could be listed on a priority basis. Manufacturers would then no doubt be willing to devote some resources to the necessary collaborative work to meet that short-list of needs. If the farmer and grower (and merchant) are to be given the greatest possible assistance, however, even this effort will need supplementing. I believe that we should make some practical use of the information already available from 1977 and 1978 Herbicide Usage Reviews, from the Pesticides Usage Survey at Rothamsted, and from W.R.O. Presumably, this information was gathered not for the sake of gathering, but because it was the intention to make use of it ! True, it is not quantitative, but it does give guidance concerning physical and biological compatability. The information does not meet the requirement of PSPS and A.D.A.S. but it provides evidence of previous experience and I think some cautious guidelines could be derived from the information - at the very least, information that certain mixtures have been reported by various bodies to have been tried with reasonable success and without obvious hazard. If we do not use the information there would seem to be little point in asking for it ! There would, of course, be an element of farmers' risk, and I realise fully that this approach would be in some conflict with current legislative trends, but I am not sure that farmers can afford to wait until industry has completed the testing required for formal clearance of the tank mixes which constitutes their major needs.

In conclusion, I believe the matter under discussion in this Session requires flexibility and co-operation from all sides - understanding by the farmer and grower - and by the merchant, so often in the 'hot seat', that to produce recommendations for tank mixes demands the use of resources which manufacturers, on the whole, prefer to devote to discovery and development; understanding by industry that they have a responsibility to do the best they can to help the farmer and grower; and understanding by M.A.F.F. that playing the game entirely and only 'by the book' will merely result in increased delays in the clearance procedure, which are already lenghy enough - there must surely be a middle way !

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HERBICIDE MIXTURES AND PROGRAMMES, THE NEEDS - WHO MEETS THEM?

THE OFFICIAL ADVISORY POSITION

P. J. Attwood

Agricultural Development and Advisory Service, Newcastle upon Tyne

In giving agrochemical recommendations the position of ADAS Advisers is apparently straightforward but in practice difficulties do arise. It is ADAS policy that Advisers are instructed to give preference to recommendations appearing on Agricultural Chemicals Approval Scheme (ACAS) approved labels. However, ADAS Advisers are also given the freedom to make recommendations that do not appear on "approved" labels with 2 important provisos: firstly, that the use is cleared under the Pesticide Safety Precautions Scheme; secondly, that the Adviser has sufficient evidence that the recommendation is sound.

In the case of approved label recommendations where mixtures and sequences are mentioned there are no problems. Clearance is dealt with as a condition of approval which is not granted without adequate evidence about the efficiency of the effects claimed. On those labels with a statement of general compatibility with other stated groups of pesticides one can assume that the safety aspects have been cleared by PSPS.

In the case of non-approved product recommendations it can also be assumed that clearance has been obtained for the mixture and sequence recommendations suggested by the label, since the Registration Authority (PSPS) reviews every word of it. (Bates 1978).

Where sequences and mixtures are between products of different manufacturers the labels themselves will usually state that the advice of the other company must be sought before the suggested action is carried out. This proviso is often repeated by ADAS because of a lack of readily available information on the physical, chemical and biological compatabilities and a desire not to give advice that might result in a claim being made against the Ministry. This is not a satisfactory state of affairs and there is a need for much more accessible information on mixtures and sequences.

ADAS is expected to be impartial and to refer to chemicals rather than brand names. However, difficulties can arise when a chemical is sold under several product names, perhaps as different formulations (eg chlormequat), some mentioning specific mixtures and others not, eg nitrogen and CIPC. An Adviser making a recommendation in this situation may name one brand in preference to another saying that he recommends it because of experience of its satisfactory use and because the manufacturers can be expected to back the claims being made on their label.

Where there are no label recommendations it is not ADAS policy to become involved in testing all the possible combinations of pesticides that might be

of use to farmers and growers. As in the minor crop situation with individual products, ADAS will never seek commercial clearance for such combinations. However, in collaboration with manufacturers ADAS can and does obtain trials clearance for mixtures used in field experiments and is happy to provide material from such trials to support a commercial clearance application by the manufacturers.

ADAS is proud to have led the field with trials of mixtures and sequences for use in oilseed rape, some of which are resulting in commercial recommendations. It has also been in the forefront with experimental evidence of herbicide mixtures used in potato crops and sequences used on sugar beet. ADAS expects to become involved in work with the more complex herbicide, fungicide, growth regulator and other chemical mixtures but does not intend to work in isolation. It is a policy decision to back a co-ordinated approach to the problem of pesticides mixtures and sequences.

With the multiplicity of possible combinations though, there is a need for a body (and BCPC is making a very useful start here) representing Advisers, farmers and the trade to identify which mixtures are most likely to be of real value in the field, and for which commercial clearance will be sought by the manufacturers, so that work can be concentrated on these.

To reiterate the official position in the case of mixtures and sequences the Adviser's position is clear: if a recommendation does not appear on a label he should not give it official backing. In other words, it cannot be an unqualified recommendation. However, on the basis of the policy decision that Advisers should be free to give advice which is best for the interests of an individual farmer and the specific advisory situation involved, he may pass on the information that he knows a particular mixture has been used frequently with no observed ill effects, that whilst the individual component products are cleared for the suggested use the mixture is not so that it is not condoned by the registration authority. The farmer is then left with the need to make a decision based on the information given. If the Adviser has any doubts about, say, harmful additive residue effects in the harvested produce, from applying a pesticide cocktail, he will express these doubts to the farmer and advise him of the ultimate risk he faces of being prevented from selling the crop if the residues are detected.

When an Adviser faces a situation where a farmer has used a concoction that may have hazardous potentialities for consumers he is then faced with the ethical decision as to whether to turn a blind eye or to make further enquiries. The latter course could lead to him having to advise that the crop should not be used for human or animal consumption until residue analysis has been carried out.

This is the extreme situation. Much more likely is the case where the Adviser can find information that the physical and chemical properties of a proposed mixture are satisfactory but is unable to obtain any guidance on its biological efficiency. Here, the Adviser will ensure that the farmer knows he carries the risk of failure himself. Unfortunately, this is likely to be a very frequent occurrence since establishing biological efficiency on a field scale beyond all doubt is long-term work because pests and diseases do not turn up to order quite as frequently as do weeds.

Many farmers and growers will not wait for the results from such long-term work and risks will be taken in a developing situation such as this where we are working at the frontiers of present knowledge. Some further examples of advisory situations may help clarify the bald statement on the official position given at the start.

In a general article or talk to a very large audience preference will always be given to approved recommendations. References to mixtures of different pesticide components will be limited because of the very limited amount of information available. Where trials reports are presented a warning that the experimental treatments should not be construed as recommendations will be given. The way in which as much information as possible is put in an official advisory publication can be found in the Weed Control Section at the recently issued leaflet, Linseed for Seed. (MAFF, 1978).

In a small group meeting or face to face with an individual farmer a wide range of mixture and sequence possibilities may be discussed. Most Advisers, after pointing out which possibilities are known to be cleared and approved, will probably then have to do some "homework" to sort out the status of the remainder. He may call upon ADAS sources such as the Regional Specialists, WRO Liaison Officers and the staff of ACAS and PSPS. He should then confirm or revise previously expressed opinions in writing.

Whilst the group meeting may often pose hypothetical problems, very real problems are often presented for immediate answer over the telephone. Wherever possible a visit will be made and very often it is found that a weed or pest situation has developed for which no firm recommendations exist, usually because the safe period for the crop has passed. In this situation the Adviser will, after checking that clearance limits including the harvest interval are satisfactory, make an "ad hoc" suggestion for a non-label treatment to be applied. He will normally confirm this in writing pointing out that it is advice for a specific situation, not a general recommendation and that no liability can be accepted it if is not effective. It seems that with the growing legislation covering the 'sale of goods' some merchants may not want to risk the liability inherent in providing goods when they know that they are to be used in ways not recommended by the manufacturers. Mr Walker's paper in this Session discusses the current position as regards disclaimers which might be made in these circumstances.

ADAS Advisers are not policemen for the Registration Authority but do have a duty to bring to the notice of appropriate departments cases of deliberate pesticide misuse where there is a clear disregard for the clearance provisos. This is not a frequent occurrence. More often Advisers become involved with the reasonable use of products in non-approved ways. They are frequently asked to investigate adverse crop effects and may well have soil and tissue analyses carried out in ADAS laboratories to assist in their diagnosis. This information is collected by our Pesticides Residues Units at Cambridge and Wye. I suggest that Units such as these could very usefully extend their activities to collect evidence useful for backing up advice about situations when certain mixtures or sequences should not be used, even if work to substantiate the safe combinations cannot always be undertaken. In addition, the information collected for the BCPC Annual Review of Herbicide Usage could be more positively quantified through such a centre.

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MIXTURES OF HERBICIDES - LEGAL ASPECTS

R.E. Walker

CIBA-GEIGY (UK) Limited, 30 Buckingham Gate, London, SW1E 6LH

Summary Those who advocate the use of mixtures of herbicides may be liable for damage or injury caused if the advice is not sound. Farmers may suffer loss and/or face substantial claims if they mix herbicides with careless disregard for the consequences of so doing. The ability of suppliers and farmers to contract out of liability is severely limited. If suppliers are not to be actively discouraged from recommending mixtures, or farmers from using them, it is desirable that resources be allocated to the collection and dissemination of information on adverse experiences with mixtures, or better still to the expansion of testing facilities.

INTRODUCTION

"What if this mixture do not worke at all?" Although this concern was expressed in Shakespeare's 'Romeo and Juliet'more in a pharmaceutical than an agrochemical context, it is typical of the anxieties exercising the minds of both suppliers and farmers when they contemplate the use of mixtures of herbicides. It is not the only one. What if it works too well? What if it causes damage, or even injury?

The first consideration to be borne in mind is Murphy's law: if anything can go wrong, sooner or later it will. The chemical compounds used in agriculture today are so sophisticated, and the knowledge of their effect on plant-life so incomplete, that some erratic behaviour can be anticipated following the mixing of even the most well tried herbicides. The question is bound to arise: Who is responsible when things go wrong, and what is the nature of his liability?

DISCUSSION

Let me outline the legal position very briefly:

1. If I sell products claiming that they are suitable for mixing with others, I am liable to the purchaser for any foreseeable losses he suffers if they are not.

2. If I advise someone in the ordinary course of business that he may safely mix two products together, I may well be liable

   (a) if he cannot safely do so;

   (b) if he could reasonably be expected to act on my advice;

   (c) if I have acted carelessly;

   (d) if I could reasonably have foreseen loss or injury of some description to the person injured; and

   (e) if loss or injury of that description has been caused to that person.

This is so regardless of whether it is my business to sell products or simply to give advice and whether or not I am paid for the advice.

3. If I experiment with mixtures myself, I can expect to pay the penalty if one of my employees is injured due to some chemical reaction taking place or if, as a result of the mixture affecting my crops in a way that renders them unfit for human consumption, a member of the public is made ill.

In a nutshell, if I sell goods they should be fit for the purpose for which they are sold; if I offer advice in the course of business, I must take care in so doing; if I mix products on my own initiative I must not do so recklessly; and even if I take the best advice available before mixing them I may still be liable - although I might well be entitled to indemnity from the person who gave the advice, if he had been careless.

It is hardly surprising in the circumstances that manufacturers and distributors, under commercial pressures as well as pressure from farmers to indicate or advise on the products that are suitable for mixing, seek to minimise their liability by disclaiming responsibility should something go wrong. To what extent can these disclaimers be relied on? Well, it all depends - which may be another way of confessing that I cannot give you a great deal of help on this point. However, I will do my best.

As far as a supplier of goods is concerned, his freedom to contract out of liability has always been at the mercy of judges, who if they can find a reason for not allowing a trader to rely on an exemption clause, will certainly do so. This is evident from the many cases on the subject. The tortuous wording of disclaimers you see on product literature or conditions of sale is the result of attempts by lawyers to plug up the holes in their clients' defences opened up by the judges. In the last decade or so this freedom has been further curtailed by a succession of Acts of Parliament starting with the Misrepresentation Act 1967 and progressing to the Supply of Goods (Implied Terms) Act 1973 and most recently the Unfair Contract Terms Act 1977. Things will get worse and not better as the impetus of consumerism carries the legislature further and further in the direction of strict liability. See for instance the Pearson Commission Report, the draft EEC Directive on Products Liability and the European Convention on Products Liability. However, let us look at the situation as it is now, not as it might be.

It is not possible to contract out of liability for death or personal injury caused by negligence. Nor can a disclaimer take away a consumer's right to recover compensation from a vendor if, for instance, the goods are not fit for the purpose for which they were sold. However, disclaimers made in a business connection, as, for example, where goods are sold to a farmer for use on the farm, or disclaimers against liability for negligence causing damage to property or financial loss will be effective if they satisfy the test of reasonableness. As far as contracts for the supply of goods are concerned, guidelines for determing whether a disclaimer is reasonable or not are set out in Schedule 2 of the Unfair Contract Terms Act 1977. They cover such matters as the ability of the purchaser to buy the same goods from someone else without the disclaimer, and also the relative bargaining strengths of the parties. In other cases, reasonableness will be judged in the light of the circumstances prevailing at the appropriate time. It is for the person seeking to rely on the disclaimer to establish its reasonableness.

The same principles apply to conditions or notices which purport to limit liability to specified sums, with the following additional criteria:

1. The resources available to meet the liability should it arise; and

2. The extent to which insurance cover against the liability is available.

It remains to be seen how the Courts will interpret and apply the new rules. I can imagine that they would be more readily inclined to uphold a disclaimer made where the supplier was making a recommendation on mixing in order to help a farmer out of difficulties, than where he was putting forward the recommendation as a selling point, but we shall see.

It is quite clear that liability only arises to the extent of the representation or warranty given. If I warrant physical compatibility only, I am not liable for biological incompatibility. If I quote the satisfactory experiences of one farmer, that by itself will not amount to a representation to another farmer that his experiences will be the same. If I advocate the application of a particular mixture on potatoes, I am not responsible if it proves useless on maize, and so on. I do not need to disclaim liability for promises I have not made.

One danger I see looming ahead is that the mixing of herbicides may become even more common than it is at the moment, due to the pressure on farmers not only to save money, but also to economise on labour and time. It may well reach the point where a manufacturer will be presumed to know of the probability of his product being mixed with others. When that point is reached the manufacturer will need to warn of any dangers of which he knows or is expected to know that are inherent in mixing the goods or applying the mixture. If the warning is not given, then regardless of whether he was aware of the danger or not, a Court will almost certainly find him liable to compensate the injured party (see Vacwell Engineering Co. v. B.D.H. Chemicals (1971) 1 Q.B. 111). The degree of knowledge attributed to manufacturers is quite amazing particularly where the product is capable of causing serious injury or death (see Wright v. Dunlop Rubber Co. (1971) 11 K.I.R. 311).

I am not in a position to assess the likely incidence or size of claims. My inherent pessimism as a lawyer warns me that the possibility of a major claim along the lines of thalidomide, due to unexpected residues in crops for human consumption - however remote that may seem - cannot be ruled out altogether, and counsels me to urge extreme caution on my commercial colleagues. At the same time, however, I recognise that there is clearly a need on the farmers' part for advice or guidance on mixtures of herbicides. If the decision of the manufacturers or distributors is that that need should be met by them, they will be encouraging the development of the situation to which I have just referred, and thereby ultimately shifting some of the risk from the farmers' shoulders on to their own. If they are prepared to accept this risk, then at the very least they should work together with Government departments or agencies, and the farmers to set up a clearing house to which details of adverse experiences could be sent and noted, in much the same way as adverse reactions to drugs are recorded.

If manufacturers and distributors do not wish to take on this risk, then they must refrain from giving advice or making recommendations until such time as they can be satisfied that the advice or recommendation is sound, not only from the point of view of physical compatibility, but also from the viewpoint of efficacy and toxicology. The farmers' need would, in those circumstances, be best met by expanding considerably the facilities for testing and approving products, perhaps on an international scale if national resources are too limited.

It is for the industries concerned to decide what they want.

I started this paper with a quotation from Shakespeare. I will finish with one from Thomas Campion written a few years later. Although he was talking about the fair sex, it could well represent a lawyer's views on herbicide mixtures:-

"Why do we need them,
When in their best they work our woe?".