4. Seed Coatings, Pelleting and other Innovative Techniques II

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SEED TREATMENT TECHNOLOGY - THE CHALLENGE AHEAD FOR THE AGRICULTURAL CHEMICALS INDUSTRY

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ABSTRACT

Seed treatment technology has improved, especially in recent years. The use of the seed "package" to deliver crop requirements for growth and development is an attractive method for potentially providing more efficient compound use and replacing wasteful foliar or soil application. This would also assist in reducing the environmental impact of agricultural chemicals but presents a challenge to the agricultural chemicals industry. New technologies now being researched will assist in the development of this concept. In the short term seed coatings will have an impact and, in the future, developments from the biotechnology boom will also play their part.

INTRODUCTION

The principle of applying chemicals to seeds to control diseases and pests is not new. There are reports of experimentation beginning in the eighteenth and nineteenth centuries with the use of copper salts, mercuric chloride, salt plus lime and formalin (Horsfall,1945; Martin, 1959). The beginning of the twentieth century saw the widespread introduction of copper based powders and the highly effective organo-mercurial fungicides, both of which are still widely used in some countries. Initially treatments were applied as aqueous steeps and later the chemicals (liquids and powders) were mixed with the seed in a heap on the floor. Mechanical applicators have been developed only recently, initially as tumble-barrels and augers (Jeffs,1986), which still remain integral parts of many present day machines.

A very large portion of the world's cereal seed is treated with some form of pesticide. In the United Kingdom almost all seeds sown in commercial agriculture and horticulture are now treated in some way. However, until recently, applying agrochemicals as seed treatments has been done only out of necessity as a means of controlling seed and soil borne pests and diseases. The development of pelleting, mini pelleting and more recently coating has stimulated a wider interest in using the seed as a carrier of other products.

This paper reviews some of these new possibilities and assesses the implications to the agricultural chemicals industry with particular reference to the market in the United Kingdom.

BACKGROUND

Seed and agricultural chemical markets

Before considering how seed treatment technology may affect the future of the agricultural chemicals industry (or indeed the seeds industry) some background information is necessary.

Since 1981 the total value of agrochemical sales per annum for the United Kingdom has risen from £230 million to approximately £360 million. Of this the herbicide sector is by far the greatest, accounting for approximately 50% of sales. During the same period the seed treatment market share has risen from £6 million (2.6% of total market) to £15.8 million (4.4% of total market - Table 1). The increase in value of the seed treatment market has been due almost entirely to the introduction of more complex, expensive products, with virtually all the market value coming from cereal seed treatments.

TABLE 1

Agricultural chemicals market by sector

	Percent market share					
	1980/1	1981/2	1982/3	1983/4	1984/5	1985/6
Herbicide	53	54	53	49	49	49
Fungicide	22	23	24	27	26	26
Insecticide	8	7	7	8.5	9	7
Seed treatments	3	3	3	3.5	4.7	4.4
Crop growth regulators	<1	1	2	2	2	2.5
Others	<--------------		to	100	---------------	-------------->
TOTAL SALES VALUE £M	229	263	298	339	365	358

Source: British Agrochemicals Association (BAA) 1983, 1984, 1985, 1986, 1987. Annual Report and Handbook

It is also appropriate to consider the value of the UK seed market, since introduction of new technologies will stimulate interaction of the two industries. Traditionally this market is divided into high volume, low value and low volume, high value types of seeds. Examples of the former are typically cereals and peas with, perhaps more controversially, oil seed rape and grass seeds being included (our traditional field crops). The latter category is represented by the vegetable seeds industry. Sugar beet seeds may be included in this latter class although the sugar beet seed treatment industry is a rather special case. For the high volume, low value crops, Table 2 gives an indication of the size and value of the current market. The high value seed sector, represented mainly by vegetables, remains a small and diverse market for seed treatments despite the attraction of high unit value. Some of the developing technologies are particularly appropriate for this market, but are not likely to present challenges to the agricultural chemicals industry unless they are also applicable to the extensive field crop sector.

TABLE 2

Seed market: volume and estimated value (for England and Wales)

	Cereals (1986/7)	Oil seed rape (1986/7)	Peas and beans (1987)	Grass mixtures inc Amenity (1987)
* Volume (tonnes)	500 704	1 814	50 809	20 000 (est)
Estimated total Market Value (£M)	120.17	6.53	22.86	40.00
(Estimated Value per tonne)	(£240)	(£3,600)	(£450)	(£2000)

* Source: NIAB Seed Production Leaflets

Cereal seed treatments account for approximately 90% of the BAA seed treatment sales figure and of this approximately 70% is attributable to sales of broad spectrum fungicide treatments. In principle, for cereal seeds, the broad spectrum products could be regarded as the beginning of the use of the seed "package", as their value for systemic mildew control is directly comparable to the cost/hectare of a foliar spray, which perhaps accounts for their commercial success.

Treatment technology - the present situation

Surveys in the early 1970's indicated two major problems of cereal seed treatments; poor achievement of overall target dose, with very few above 75% and many at approximately 50%, and large seed to seed variation (Lord et al. 1971a, 1971b; Jeffs et al. 1972).

Recently a greater awareness of the requirement for better quality seed treatments has led to improvements in application equipment and formulations so that loadings are now more usually in the range 75 - 100%, with many at the 90% level (R. Noon ICI Plant Protection - personal communication, T.J. Martin, Bayer Agrochemicals UK Limited - personal communication).

Pelleting and minipelleting are used in specific crops e.g. sugar beet and some vegetables, to produce seeds of uniform size and shape for precision sowing and to improve application of pesticides. Pelleting of cereal seeds may also give more uniform individual seed loadings, but is unlikely to be practical (Jeffs and Tuppen, 1986). Recently, seed coatings have been developed which give accuracy of application and practicability but need not affect seed shape. This technology has the potential to dramatically affect future developments in seed treatments for all crops providing that practical application equipment can be developed.

THE FUTURE FOR SEED TREATMENT TECHNOLOGY

Pressures for change

The agricultural industry generally is the subject of much debate. The present overproduction has stimulated a review of methods of production so that supply can more closely meet demand. Pressure for change is growing and will become stronger, resulting in a more exacting, economic environment for agriculture and the necessity for farmers to make more efficient use of inputs.

In addition to this economic pressure there is also a much greater interest in the possible environmental effects of modern farming methods. This has led to an examination of the necessity for the extensive use of pesticides and fertilisers and of the impact that they may have on our environment.

It would be wrong to make too much of these environmental pressures but they do present an opportunity for self-examination. It is generally accepted that widescale commercial production of agricultural products will not be possible without a chemical input, but action will be necessary to achieve more efficient, and if possible, less frequent use of chemicals. These pressures , in fact, present major challenges to the industry.

One very positive reply to most of these criticisms and problems can be related to seed treatment technology. Using seeds as a vehicle for applying agricultural chemicals to crops reduces the need for potentially wasteful field applications. The relatively small amount of research to date indicates that using seed as a vehicle to carry the plants requirements for growth and development is a very attractive principle, and it is this total package which will have a major effect on the agricultural chemicals industry.

The technology of the seed "package"

The seed "package" concept suggests a requirement for a pelleting or coating. In the vegetable seed industry, coatings have become common in situations where accurate seed treatments are required, but where an increase in seed size from pelleting would be a disadvantage. It is now generally accepted that coating can be defined as the production of a "second skin" around the seed, usually achieved by increasing weight by less than 5%.

However, in producing a new product in combination with a coating, there are three essential disciplines to research: application equipment design, film-forming materials and formulations and new pesticides for inclusion in the package. In general terms success will be achieved if research and development is directed towards producing formulations which do not deleteriously affect seedling development or the biological performance of the pesticide. Coating application equipment has been produced for vegetable seeds using various principles, and with varying degrees of success. This suggests that the interactions of the whole system, i.e. equipment, film former and included materials, must be evaluated properly in each case to ensure good results. For high volume, low value seeds throughput has to be high enough to satisfy the needs of a commercial processing warehouse which is, at present, one of the major obstacles to success. However over the last few years very rapid progress has been made by several commercial companies in producing systems for peas, oilseed rape and cereals. Seed coating technology is therefore poised to start a new era in the seed treatment industry by improving quality, and providing a vehicle by which pesticide use can gradually be transferred to application in the seed "package". Some of these possible new developments are described below.

Accuracy, uniformity and good adhesion

Accurate, uniform and strongly adherent coated products all contribute to each seed having the correct amount of active ingredient. This will improve performance, reduce phytotoxicity (McKinlay, 1982; Clayton *et al.* 1987) and ultimately reduce the dose rates required. Many of these benefits are achieved by a relatively high volume application of an appropriate film former which can also ensure that new very active molecules, usually required in very small amounts, can be accurately metered out to each seed. This may have the additional benefit of reducing phytotoxicity of some products.

If the coating material is matched correctly with the active ingredients it is to apply, then there will be no deleterious effects, and loading uniformity can be improved considerably (Table 3).

TABLE 3

Individual seed loadings for different application methods for a broad spectrum seed treatment

	Application method		
	Conventional	Coat 1	Coat 2
Mean loading *	86.0	89.2	95.2
Range	45.8 - 188.6	54.8 - 136.8	75.7 - 118.5
95% confidence limit	71.5 - 100.5 (+ 14.5)	79.9 - 98.5 (+ 9.3)	90.9 - 99.5 (+ 4.3)

* Values are all expressed as percent of target dose rate.

Results quoted are from 40 individual seeds from each sample, analysed by a UV spectrophotometric method. All applications were applied using a laboratory "Rotostat".

In another experiment using a coating system to apply iprodione to cabbage seeds, it was reported that this system achieved more uniform seed loadings than conventional dust or slurries and suggested that better control of Alternaria brassicae may have been achieved (Maude and Suett, 1986).

High loadings

To achieve certain technical goals, a high amount of active ingredient or product is required, which cannot be applied satisfactorily by conventional means. The correct choice of coating system in these circumstances permits this to be achieved, for example with fungicide plus insecticide mixtures for peas (Baughan and Toms, 1984; Salter and Smith, 1986) and the use of calcium peroxide on grass seeds (Ollerenshaw, 1985).

The use of micronutrients is increasing and to be most effective they are required from the commencement of growth. Since the leaf area at this stage is extremely small, foliar sprays are only partially effective and soil treatment would require very high dose rates. High doses of manganese coated onto cereal seeds have been successful in improving young plant growth and, in conjunction with follow-up foliar manganese sprays, have given good yield increases (Clayton et al. 1987). Using a coating system to achieve these high loadings introduces new possibilities for existing chemicals in the short term and increases the opportunity for achieving new products in the longer term.

Multilayered coats

The technology for producing a multilayered coat has already been used to control the onset of germination by physical means (Schreiber and LaCroix, 1967). Multilayers can also achieve the application of products which are, for various reasons, incompatible and may require two or more passes through a conventional machine. This technology can also be developed to achieve a physical separation of pesticides, which may be phytotoxic, from the immediate vicinity of the seed, so affording some protection. The inclusion of a specific barrier or buffer coat to increase this physical separation can improve this protection. Use of such a physical separation has been successful where rhizobia have to be applied with certain pesticides (Roughley, 1980). By using this technique the portfolio of products available as seed treatments can be increased.

Application of controlled-release pesticides and biological control agents

Two technologies receiving wide publicity and interest are controlled release mechanisms for pesticides and the use of biological control agents (BCA's). In both cases the development of coating technology to facilitate their use in the seed "package" would be especially appropriate. The application of an insecticide programmed for sequential release would give season long control without the associated "peaks and troughs" from traditional sequential field applications. Research input to achieving controlled release has increased and, in conjunction with a coating system, will provide a convenient method of delivery and an opportunity to reduce the total amount of product necessary to be effective. This in theory provides the most efficient mechanism - better, more uniform control and less product applied (although not necessarily less expensive). Again this is an example of a new technology being appropriately used as part of a seed "package".

The "biotechnology boom" encompasses many exciting disciplines which may not necessarily be developed as seed treatments but which may bring major changes to the agricultural chemicals industry. Examples are already being identified of biological agents for the control of pests and diseases for field application which if successfully developed will take a share of the chemicals market. However this should be regarded as a substitution rather than competition and the challenge will be in adapting to produce these products, with their very different requirements compared to chemical production. By contrast it is possible that, by genetic manipulation, crop plants can be given "new genes" which reduce the need for application of chemicals. This would of course be a competitive threat and may be a longer term challenge, but in reality it is expected that both chemical and genetic approaches will continue to be used.

Many examples of the use of biological control agents already identified are in the rhizosphere and can be divided into two types, those which control specific pests or diseases and those which promote plant growth. Studying the interaction of seed coating formulations with the BCA's will be critical because very different coat qualities are required to successfully apply and maintain viability of a living organism compared to simply applying chemicals. For a seed coating formulation to successfully apply any BCA it must provide uniform distribution and correct loading of inoculum, maintain viability for an acceptable period and provide seed which is easy to handle and drill all at a realistic cost. The control of the microenvironment to stimulate bacterial growth once the inoculated seeds are in the soil would be an advantage and can be achieved in the "package" by developing formulations which include appropriate nutrients and moisture controlling materials. This of course demands special attention to the film-forming part of the package.

Simple experiments have demonstrated the feasibility of coating on, and maintaining viability for,traditional rhizobial inoculant (Roughley, 1980) and recently for BCA's of various types (Suslow and Schroth,1982; Weller,1983; Hubbard et al.1983). Generally in these experiments the use of adhesives and coatings has been to aid the retention of inoculant with very little attempt to optimise the "package" of coating formulation plus inoculant.

Application of products not traditionally used as seed treatments

With the appropriate manipulation of seed coating formulations, new opportunities exist for the effective application to seeds of products which have been traditionally field applied. For example, crop growth regulators still have an effect when seed applied (De et al. 1982, Woodward and Marshall,1987). Seed coating technology now offers an opportunity to optimise this effect.

Similarly, with herbicides, which have not been available as effective seed treatments, an opportunity exists to successfully achieve control of some weeds in certain crops by applying them in special coatings. An example of this success has been with the herbicide EPTC on alfalfa seeds (Dawson,1981) and with a wider range of grass weed herbicides on soya and cotton (Dale,1983). It is now conceivable that sections of the herbicide market, (the largest of the agricultural chemical sectors) can be converted from field application to a seed coating application. This of course would be a considerable challenge for the agricultural chemical industry's traditional herbicide market but offers an opportunity to maintain profitability while reducing total amounts required.

There are other examples of products normally field-applied being effective when used in a coating and in many cases at reduced dose rates. Several of these examples are with insecticides which would normally be applied to the soil as granules, for example for control of carrot fly (Thompson et al. 1983) and on peas for Sitona control (Baughan and Toms, 1984). It is envisaged that by the use of the appropriate coating technology other products, many of them normally soil or foliar applied (e.g. molluscicides, bird and mammal repellents, growth stimulants and nutrients) will become part of a successful seed "package".

Further investment in these areas will lead to the production of more suitable and effective combinations which will ultimately reduce farmers' costs, certainly reduce labour requirements and prove to be better farming practice and more desirable for the environment.

SUMMARY

Advances in seed coating technology confirm its potential for pesticide application and as such will present a challenge to the agricultural chemicals industry in the development of application equipment and formulations. The application of coating technology to other new developments will result in exciting and beneficial seed-applied products which may present new challenges to the agricultural chemicals industry.

At present the seed treatment sector is the poor relation in the agricultural chemicals industry. The market is small and different. However in its correct perspective in the UK it is a bigger market than that of crop growth regulators, which has been suggested as being the next growth sector. What is needed now is an acknowledgement by the agricultural chemicals industry that coatings offer a valuable market opportunity which requires a suitable resource commitment to ensure its successful development and profitability as a highly desirable alternative to the more environmentally-sensitive field applications.

Perhaps, then, the challenge that the seed treatment technology poses is one of development and not competition for the agricultural chemicals industry.

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SEED ENCAPSULATION METHODS FOR CONTROL OF STORAGE FUNGI

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ABSTRACT

Fungi in the *Aspergillus* and *Pencillium* species are a major cause of decay, and loss of germinability of seeds stored at relative humidities greater than 75%. Uptake of moisture was greatly reduced in soybean seeds, treated with a polyvinylidene chloride copolymer emulsion (Daran), after 2 months storage at 85% relative humidity. The material was applied either at rate of 8 g/ kg seed with a Gustafson Batch Laboratory Treater, designed to coat small samples of seeds with agricultural chemicals, or at 50 g/ kg with a Vector/Freund Hi-Coater, designed to coat pharmaceutical tablets. The latter treatment provided a more effective moisture barrier. Seed germination was greatly reduced when measured immediately after encapsulation, but after storage for 2 months at 85% relative humidity, it was similar to that in the untreated control lots. Daran, applied to maize seeds at 50 g/ kg in the Vector/Freund apparatus, was an ineffective moisture barrier. The fungicide thiabendazole, however, controlled storage fungi and prevented loss in germination potential. Scanning electron micrographs revealed flaws in the integrity of encapsulation coats that could be related to application methods.

INTRODUCTION

Adverse effects of storage fungi on seeds and grain stored at moisture contents in the 14 to 20% range are well-documented (Christensen & Meronuck, 1986). Storage fungi are members of the *Aspergillus* (Asp.) and *Penicillium* (Pen.) species. They invade seeds, causing loss in germination potential, and general decay. Control can be achieved by drying seeds to safe moisture levels, and maintaining these levels with aeration. In temperate regions of the world this practice usually is effective, but in tropical areas, where humidity and temperatures are high, it is difficult to maintain safe storage moisture levels without controlled environment facilities. Recently there has been renewed interest in chemical control of storage fungi, based on the evidence that benzimidazole fungicides greatly reduced storage fungi invasion of maize seeds stored at 85% relative humidity for 3 months (Moreno-Martinez & Ramirez,1985).

Seed encapsulation, with materials that would restrict uptake of moisture from the storage environment, offers another possible control method. Successful materials must be nontoxic to the seed, easy to apply and provide an effective moisture barrier. Treated seeds also would have to be capable of germinating when planted in the field. Recently, a polymeric material, Daran 220, applied to soybean seeds, showed potential as a moisture barrier when tested over the first 24 hours of exposure to high humidity (West *et al.* 1985). Its effectiveness over long term storage was not demonstrated, however.

The present study examined factors influencing the efficacy of moisture barriers alone, and in combination with the fungicide thiabendazole, for control of storage fungi invasion in maize and soybean seeds.

MATERIALS AND METHODS

Application of test materials

The material, Daran 220, studied by West *et al.* (1985), was examined in this project in two formulations, Daran 220 and Daran 8600. This is a polyvinylidene chloride coploymer emulsion, manufactured by W. R. Grace and Company, Lexington, MA. Maize or soybean seeds were treated with these materials, either alone, or in combination with the benzimidazole fungicide, thiabendazole (TBZ). The formulation Mertect 340F was used. Materials were applied with a Gustafson Batch Laboratory Treater, designed to treat small samples of seeds with agricultural chemicals. Seeds are held in a rotating drum and the chemicals applied with a spray gun. A second application method used a Vector/Freund Hi-Coater, designed to coat pharmaceutical tablets. In this equipment, seeds are held in a rotating drum, through which air flows at controlled temperature and humidity. Chemicals are added through air atomization spray guns.

Storage conditions

Treated seeds were placed in plastic boxes, (one box for each of three replicates of each treatment) and stored in chambers at various temperatures and relative humidities. Humidity was controlled by inserting trays containing pads, soaked in glycerol:water solutions, in the chambers. The chambers were held in constant temperature rooms. Temperature and relative humidity were monitored with hygrothermographs.

Sampling

Seed samples were drawn from treatments periodically during storage. Seed moisture was tested by oven drying at 103°C for 24 h. In one test, 45 g lots of seeds, for each encapsulation treatment, were exposed to different environmental conditions in petri dishes with perforated lids. Weight changes in the seeds over a two month period were used to estimate moisture exchange. Germination was measured by incubation on wet blotters for 7 days at 25°C. One hundred seeds were tested for each replicate. Storage fungi invasion was determined by surface sterilizing the seeds in 1.0% sodium hypochlorite for 1 min, rinsing in sterile water, and incubating on malt-salt agar for 14 days at 25°C. Fifty seeds were plated per replicate.

RESULTS

Daran 220, applied to maize seeds with the Vector/Freund equipment, was an ineffective barrier to uptake of moisture from an 85% relative humidity atmosphere over three months of storage (Table 1). Seeds were invaded with storage fungi to the same degree as the untreated control lots, and germination was greatly reduced. TBZ treatment did not restrict moisture uptake but storage fungi invasion was controlled, and germination was not reduced.

TABLE 1

Moisture content, germination, and storage fungi invasion of maize seeds treated with encapsulation materials, before and after storage at 85% relative humidity and 25°C for three months.

Encapsulation Material	Rate/ kg seed	Storage period (mo)	Moisture content (%)	Germination (%)	Storage fungi (%) Pen.	Asp.	Total
Daran 220	50 g	0	9.6	95.4	10.7	3.3	14.0
		3	17.6	15.4	70.7	36.6	100.0
TBZ	1.1 ml	0	8.9	98.7	1.3	0.0	1.3
		3	18.5	95.4	10.7	9.3	20.0
Untreated		0	8.7	94.6	4.0	0.7	4.7
		3	17.6	3.3	10.0	100.0	100.0

Moisture exchange over two months with low (50%), and high (85%) relative humidity environments was compared for soybeans treated with various encapsulation materials (Table 2). Moisture moved out of seeds at 50% r.h. and into them at 85%. Both formulations of Daran, either alone or in combination with TBZ, reduced the rate of uptake in the 85% r.h. environment. Daran 220, applied at 5 g/100 g seeds in the Vector/Freund treater, was a more effective moisture barrier than all the other treatments, except for Daran 8600 + TBZ, applied at the same rate by the same equipment. It was not possible to apply the higher rate of material with this Gustafson treater without damaging the seed.

Germination was greatly reduced after seeds were treated with encapsulation materials (Table 3). This effect was particularly obvious when measured at the beginning of the storage period, and was more pronounced in seeds treated at 50 g/kg with the Vector/Freund treater. After 2 months storage at 50% r.h., germination values were similar to those at 0 months. At 85% r.h., however, it increased markedly for all treatments.

Scanning electron micrographs showed the natural seed coat of untreated seeds (Fig. 1) and imperfections on the surfaces of encapsulated seeds (Figs. 2 and 3). Elongate cracks occurred, as indicated across the hilum of a seed treated with Daran 8600 at 8 g/ kg of seeds (Fig. 2). Another problem developed when seeds adhered together after coating. Fig. 3 shows an area of the underlying seed coat exposed, when the point of attachment between two such seeds was broken.

TABLE 2

Change in the original seed moisture content, after one and two months storage in two storage environments in soybean seeds treated with encapsulation materials.

Application equipment	Encapsulation Material	Rate/ kg seed	% Change in moisture content* in the environments			
			50% r.h./ 10°C		85% r.h./ 25°C	
			1 mo	2 mo	1 mo	2 mo
Vector/ Freund Hi-Coater	Daran 8600	50 g	-0.7	-1.3	+4.0	+4.5
	Daran 8600 + TBZ **	50 g 0.35 ml	-0.3	-0.6	+1.2	+1.5
	Daran 220	50 g	-0.3	-0.6	+1.7	+2.2
	Daran 220 + TBZ	50 g 0.35 ml	-0.3	-0.6	+1.7	+2.3
Gustafson BLT	Daran 8600	8 g	-1.0	-1.7	+2.5	+3.4
	Daran 8600 + TBZ	8 g 0.35 ml	-1.3	-2.1	+4.2	+4.4
	Daran 220	8 g	-1.2	-1.8	+3.0	+3.4
	Daran 220 + TBZ	8 g 0.35 ml	-0.8	-1.4	+2.5	+3.4
	TBZ	0.35 ml	-1.3	-1.9	+6.1	+5.9
	Untreated		-0.9	-1.6	+5.6	+5.8

* These values are based on the weight change (g) of 45 g of seed for each treatment since the storage period began
** Talcum powder was added to the coating mixture.

TABLE 3

Germination before and after two months storage in two storage environments for soybean seeds treated with encapsulation materials.

Application equipment	Encapsulation Material	Rate/ kg seed	Germination (%) after storage at 50% r.h./ $10^{o}C$ 0 mo	2 mo	85% r.h./ $25^{o}C$ 0 mo	2 mo
Vector/ Freund Hi-Coater	Daran 8600	5 g	14.0	11.8	14.0	87.2
	Daran 8600 + TBZ **	5 g 0.035 ml	2.0	1.2	2.0	70.8
	Daran 220	5 g	3.0	2.0	3.0	43.7
	Daran 220 + TBZ	5 g 0.035 ml	15.0	11.7	15.0	77.2
Gustafson BLT	Daran 8600	0.8 g	55.0	68.3	55.0	88.3
	Daran 8600 + TBZ	0.8 g 0.035 ml	87.0	85.0	87.0	94.0
	Daran 220	0.8 g	57.0	37.0	57.0	84.5
	Daran 220 + TBZ	0.8 g 0.035 ml	40.0	28.0	40.0	82.8
	TBZ	0.035 ml	98.0	96.3	98.0	98.5
	Untreated		97.0	96.2	97.0	98.0

DISCUSSION

Daran formulations, tested in this study, reduced the rate of uptake of moisture, were nontoxic to seeds, and could be applied to seeds with treating equipment. They met, to a significant degree, the criteria for successful moisture barriers. Clearly much work remains to be done to produce effective, and economically feasible, encapsulation treatments.

Fig. 1 Scanning electron micrograph of the surface of an untreated soybean seed.

Fig. 2 Scanning electron micrograph of a crack in the encapsulation coat on a soybean seed treated with Daran 8600.

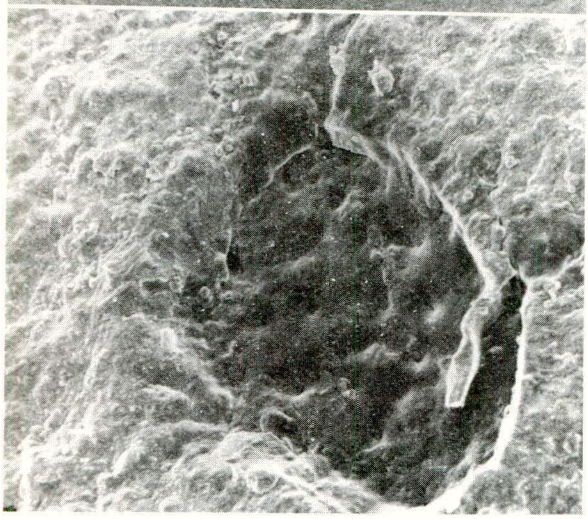

Fig. 3 Scanning electron micrograph showing a section of encapsulation coat removed by an adhering seed. The seeds were treated with Daran 8600.

Several significant problems in this technology have been identified. It is unlikely that an encapsulation treatment can totally inhibit moisture uptake. Some measure of gaseous exchange will occur, allowing water vapor to pass through the coating. Gaseous exchange is, in fact, necessary to ensure seed survival for physiological reasons. By reducing the rate of uptake of moisture, however, the storage period before which storage fungi could invade seeds, might be extended. By including a fungicide such as TBZ in the encapsulation material, storage fungi invasion could be further delayed. The combined effect of a moisture barrier and fungicide could, therefore, could provide safe long term storage of seeds at high humidity.

The efficacy of the encapsulation material will depend on the integrity of the coat. Cracks in the coat, as seen in Fig. 2, will provide an avenue for entry of moisture. In this study, higher application rates of Daran improved the moisture barrier, possibly by reducing numbers of cracks. Constraints on using high application rates are the availability and cost of materials, and application equipment. The Vector/Freund treater is extremely expensive to purchase and operate. Other seed treatment equipment, such as fluidized beds, may prove to be more economic than rotating drum systems. They also may reduce the problem of coat damage caused by seeds adhering to each other. The most effective treatment in the present study contained talcum powder in the encapsulation mixture to reduce sticking.

There undoubtedly are other characteristics of the coating methodology, hitherto unidentified, that would have a strong influence on the integrity of the coat. Different rates of application were used in the present study, hence the two pieces of equipment could not be compared. The Vector/Freund system is, however, a far more sophisticated apparatus than the Gustafson treater, and may well have been responsible for the improved moisture barrier. Another consideration in encapsulating seeds is the seed shape. Daran 220, gave an effective barrier when applied to the smooth spherical soybean seeds, but was ineffective, at the same application rate, on the more irregular maize seeds.

The improved germination of Daran treated seeds, stored for 2 months at 85% relative humidity, had both positive and negative features. Obviously, the coating must allow the seed to germinate, but germination also indicated deterioration in integrity of the coat. It would seem that the gradual uptake of moisture caused some seed swelling, and concomitant breakage of the coat. Materials might be found that would have greater elasticity to avoid cracking. At some point in the storage period, however, it would be advantageous for the barrier to break down, in order to allow germination to proceed. Alternatively, the barrier can be broken mechanically.

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RECENT DEVELOPMENTS IN SUGAR-BEET SEED TREATMENTS

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ABSTRACT

Following the change from the clay to the organic pellet in 1984 there has been a re-appraisal of the pesticide treatments applied to sugar-beet seed. The short duration steep in ethyl mercuric phosphate for controlling seed-borne *Phoma betae* is to be replaced in 1989 with a prolonged steep in thiram prior to pelleting. This has been shown to give benefits additional to disease control by increasing the rate of seedling emergence and the number of established plants.

The incorporation of hymexazol in the seed pellet for the control of soil-borne damping-off fungi is to be extended to all 250 t of seed in 1988. Alternatives to methiocarb, incorporated in the pellet since 1978, for controlling seedling pests such as springtails, symphylids, millipedes and pygmy beetle, are being sought. In particular, the possibility of improving efficacy by using a mixture of a carbamate with a pyrethroid insecticide is being explored.

INTRODUCTION

To achieve maximum yield, sugar-beet crops need 75 000 plants/ha, spaced evenly. However, because some seeds fail to give plants, farmers sow more than 100 000 seeds/ha and aim to achieve 70% establishment. Unfortunately, two thirds of the national crop still fails to achieve this level of establishment and part of this shortfall is due to pests and diseases (Durrant, Scott & Jaggard, 1984). Insecticide and fungicide seed treatments offer the potential for improving plant establishment at low cost.

Monogerm sugar-beet seed has a discus-like, flat shape, which required pelleting to make it easier to sow in precision drills when it was first introduced in the 1960's (Prince, 1986). Pelleting also allowed crop protection chemicals, particularly insecticides that had formerly been applied to the seed, to be incorporated into or onto the pellet material; this improved retention of the chemical and also reduced the risk of phytotoxicity (Winder, 1986). Dieldrin was incorporated in the pellet to control soil inhabiting arthropod pests until 1978, when pressure from the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage led to the withdrawal of this persistent organo-chlorine compound and its replacement by methiocarb, which is still used on all sugar-beet seed sown in Britain (Winder, 1986).

Since 1962, seed-borne Phoma betae, the most important fungus attacking sugar-beet seedlings, has been controlled by steeping seed for 20 minutes in a 40 mg/l solution of ethyl mercuric phosphate (EMP) before pelleting (Payne,1986). An additional treatment of hymexazol incorporated into the pellet at a rate of 10.5 g a.i./kg of seed to control soil-borne Aphanomyces cochlioides, which causes blackleg, has been available on about 30-40% of seed since 1983 (Payne,1987).

Until 1984 these insecticide and fungicide treatments were incorporated into a clay-based pellet marketed in Britain by Germain's U.K. as 'Filcoat'. However, experiments in the early 1980's suggested that Germain's EB3 pellet, which contained a high proportion of 'wood flour', allowed faster emergence than 'Filcoat' especially under adverse field conditions (Durrant & Loads,1986). The EB3 pellet replaced the 'Filcoat' pellet in 1985. This radical change in pelleting material coincided with a re-assessment of pesticide treatments applied to sugar-beet seed, and this paper reviews the progress made since the introduction of the new pellet.

FUNGICIDE TREATMENT OF SEED

EEC regulations governing the use of organo-mercurial fungicides have threatened the continued use of EMP. Since 1962 many alternatives have been tested but only a steep in thiram (2 g a.i./l suspension at 30°C for 24 hrs) (Agrichem Ltd.) has given control of P.betae comparable with that of EMP. The prolonged soaking involved in this treatment had the additional benefit of increasing the rate at which seedlings emerged (Byford,1985).

Recent experiments determined the effect of reducing steep duration and temperature to maximise both disease control and physiological advancement (Durrant & Loads,1987). In four field experiments between 1983 and 1985, establishment of seed steeped in thiram for different durations at 20°C and 30°C was never less than, and sometimes significantly exceeded, that of EMP-treated seed and often emergence occurred earlier. However differences between thiram steeps were small and not consistent between experiments (Payne,1986). Table 1 shows the results of an experiment where responses to fungicide were greatest.

TABLE 1

Effects of seed treatments on final plant establishment and rate of seedling emergence: 1983 experiment (40% seeds infected with Phoma)

	Un-treated	EMP	0.2% thiram steep at 20°C			0.2% thiram steep at 30°C		
			6 h	15 h	24 h	6 h	15 h	24 h
%establishment*	42.0	58.3	59.9	61.2	59.0	62.1	61.4	62.1
$t_{50\%}$(days)**	13.0	13.3	12.4	12.1	12.0	11.7	11.8	11.9

* after angular transformation (5% LSD = 3.0)
** time taken to achieve 50% of final emergence (5% LSD = 0.46)

Extensive comparisons made by British Sugar plc in more than 300 fields during the last 3 years showed that, on average, thiram gives quicker emergence and about 3% more plants than EMP. As a result all sugar-beet seed sown in Britain will, from 1989, be treated with thiram (8-16 h steep at 25°C) prior to pelleting (Prince, 1986). This change in seed treatment should produce a small but valuable improvement in rates of emergence and the establishment of the crop in this country.

FUNGICIDES IN THE PELLET

Recent work on seed treatments to control seedling diseases caused by soil-borne fungi has sought to determine the optimum rate of hymexazol (Sumitomo Corp.) for incorporation in the new organic pellet, and to assess whether it is justified to use the treatment on all seed sown in this country.

In a series of sixteen field experiments over a wide range of sites and sowing dates undertaken by British Sugar in 1985 and 1986 the effect of incorporating hymexazol in the EB3 pellet was tested at up to six rates ranging from 1.75 to 17.5 g a.i./kg. The number of seedlings established was increased slightly by hymexazol treatments at all sites in 1985 and at some sites in 1986. In the four experiments where there was direct evidence of a moderate attack by Aphanomyces cochlioides (Table 2) all hymexazol treatments significantly increased seedling establishment and decreased the number of seedlings with symptoms of infection. There were no consistent differences in disease control between fungicide rates but, in the sixteen trials overall, the addition of hymexazol at 3.5 g a.i./kg was frequently associated with earlier emergence of seedlings compared with untreated seed or seed with higher rates of hymexazol. This fungicide has been reported to have beneficial effects on seedling growth of some other plant species, unrelated to disease control (Tomita *et al.* 1973).

TABLE 2

Effect of hymexazol in the EB3 pellet on establishment of sugar-beet seedlings and disease caused by *A.cochlioides*. Mean of four experiments: 1985-86.

Rate of Hymexazol (g a.i./kg seed)	Percent final establishment	Percent infection of surviving seedlings
0.0	44.7	14.1
3.5	60.1	5.3
7.0	57.9	2.0
10.5	58.2	2.4
14.0	59.1	1.4
5% LSD	8.9	6.4

The small increases in establishment found in these experiments, with no evidence of phytotoxicity, would suggest that the general use of hymexazol is justified and from 1988 all sugar-beet seed sold in the U.K. will be treated with this chemical at 10.5 g a.i./kg. Further work is required to determine if a lower rate should be adopted for general use, particularly if the growth promoting effect of hymexazol at this lower rate can be confirmed. The 10.5 g/kg rate would then be used only in disease-prone conditions eg. late sown or resown crops.

INSECTICIDES

Methiocarb (Bayer U.K. Ltd.) as a seed treatment has only ever been regarded as a partial, but cheap, insurance against soil inhabiting arthropod pests. In fields where there is a risk of serious pest attack growers are recommended to supplement the seed treatment by applying granular insecticides in the seed furrow (Winder & Cooper, 1984). However, this practice has become widespread even in fields where pests are few or absent (Dewar & Cooke, 1986). Better seed treatments are being sought in the hope that this will give many growers the confidence to dispense with granules.

Methiocarb was originally chosen as a replacement for dieldrin because of its efficacy against pygmy beetles (Atomaria linearis), but it was never very effective against other, more common pests, such as Onychiurus armatus, Scutigerella immaculata and Blaniulus guttulatus (Dunning & Winder, 1971). The methiocarb application was restricted to 2 g a.i./kg due to its phytotoxic effects at higher doses. Several newer pesticides are less phytotoxic and initial trials in 1982 and 1983 with both the 'Filcoat' and EB3 pellets showed that some of the insecticides were at least as good as methiocarb. They could be used at higher rates with little or no adverse effect on emergence and vigour, and could be incorporated in the new organic pellet with no decline in activity (Winder & Cooper, 1984).

Since 1983, a further 33 trials have been conducted over a range of soil types on sites with varying densities of pests. In these sites methiocarb gave only marginal, if any, improvement in establishment of the untreated seed (Table 3) (Winder, 1986). The carbamates bendiocarb (Schering AG Ltd.), benfuracarb (Farm Protection Ltd.), carbosulfan (FMC Corp.), and furathiocarb (Ciba-Geigy Agrochemicals) frequently performed better particularly at medium and high rates of application (Table 3). The soil-stable pyrethroid tefluthrin (ICI plc) was also effective, more so at the lower rates of application, suggesting that the highest rates were slightly phytotoxic. Of these materials, both bendiocarb and benfuracarb were withdrawn from the trial series in 1986, the former due to its instability in the pellet, and the latter due to occasional but severe phytotoxicity at the higher rates (Winder, 1986).

The range of materials has now been narrowed down to carbosulfan, furathiocarb and tefluthrin, all of which performed well in 1987 although emergence and establishment even of untreated seed, was good in that season. Over all sites, furathiocarb was the better of the two carbamates when applied at 60 g a.i./kg but carbosulfan at 45 g a.i./ kg was also good. Tefluthrin gave consistently better results than either carbamate (Table 3).

TABLE 3

Average seedling establishment (seedling numbers as percentage of seed sown) obtained with various insecticide seed treatments in trials in 1984 - 1987.

Treatment	g a.i./kg seed	1984 9 trials	1985 9 trials	1986 5 trials	1987 10 trials	All 4 years
no insecticide		64	61	66	74	66
methiocarb	2	66	63	63	73	66
bendiocarb	4	69	62	-	-	
"	8	68	59	-	-	
"	16	68	-	-	-	
benfuracarb	4	-	64	-	-	
"	30	69	61	-	-	
"	60	67	36	-	-	
carbosulfan	4/5	-	61	65	-	
"	30	71	61	69	71	68
"	45				74	
"	60	67	61	67	72	67
furathiocarb	4/5	69	63	-	-	
"	30	66	64	71	72	68
"	45				73	
"	60	71	64	71	75	70
tefluthrin	4/5	-	67	71	-	
"	15	-	-	73	79	
"	30	72	66	73	79	73
"	60	-	59	73	-	
carbosulfan + tefluthrin	30+15	-	-	75	74	
furathiocarb + tefluthrin	30+15	-	-	76	78	

Both of the carbamates and tefluthrin have some disadvantages. Furathiocarb and carbosulfan may fail to give adequate early protection due to their relatively slow breakdown to the more insecticidally active carbofuran, and may be susceptible to enhanced biodegradation: tefluthrin lacks systemic activity to provide protection against foliar pests. To overcome these shortcomings, mixtures of tefluthrin with carbamates have been tested recently. No adverse interactions between the chemicals were noted and establishment of plants was intermediate between the pyrethroid and the respective carbamates. Unfortunately, foliar pests such as flea beetles were not damaging at any site in 1986 or 1987, so the advantage of mixtures has yet to be demonstrated. Trials with very large plots are now planned in 1988 to compare these materials over a larger range of soil types with a view to introducing a new pesticide treatment by 1989. Further work will continue to examine the benefits of mixtures of insecticides at sites where a wider range of pests is anticipated and to investigate potential interactions between insecticides and fungicides within the seed pellet.

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"SHR": COATING TECHNOLOGY FOR APPLICATION OF PESTICIDES TO SEEDS

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ABSTRACT

In 1978 SUET developed and patented a coating process for fungicides/insecticide application to seeds. Supplied by hot air, a fountain of seeds recycles within a conical vertical cylinder. Complete, uniform and accurate coating under a defined temperature regime is controlled by atomizing the pre-homogenized aqueous suspensions and instant redrying of the seeds surface.

Batch or semi-continuous units are designed with exhaust, filter and dust recycling systems as well as rinsing water recycling for safe and hygienic operation. Pesticide loadings on single seeds are determined by tlc. Assessment of pesticide concentrations and availability of protective ingredients to the seeds can be analyzed *in vitro* and during plant development.

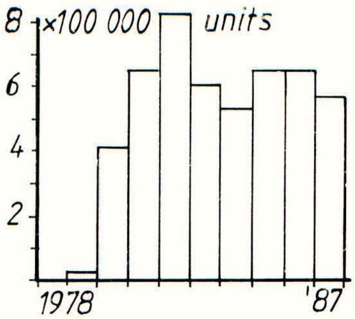
INTRODUCTION

SUET Saat- und Erntetechnik GmbH is a service company in seed processing. In 1978, SUET started an advanced system of coating seeds and seed pellets with fungicides, insecticides and other ingredients (Pat. DE 29 40 263, EP 0047 795). This "SHR" system (Spraying, Homogenizing, Redrying) provides machinery and process control for the gentle movement of seed particles and the suspension of coating materials homogenized for complete, uniform and accurate coating. Adequate analytical methods ensure product development and product quality.

Research, together with information exchanged with customers and institutes indicate 4 major requirements for attaining optimum protection and technical performance of seeds:

- high precision in dosing of pesticides to the single seed
- high standards of safety and hygiene for operators and product users
- homogenous, complete, nonabrasive surfaces to improve handling and sowing
- continuous evaluation of pesticide combinations with trials on efficacy again pests and fungi. Compatibility of seed quality, germination, vigour and shelf life are also studied.

In 1980 the volume of pelleted coated beet seeds processed by the company amounted to 600 000 units per year (1 unit = 100 000 grains), or 1 800 tons. It is also now more than 65 000 kgs annually of coated onion, carrot and other vegetable seeds, treated with the broad range of fungicides and insecticides formulated in European countries (Fig. 1).



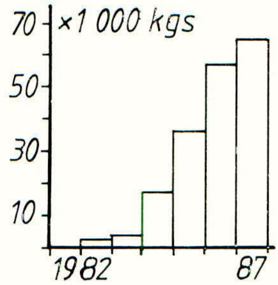


Fig. 1. SHR coated beet seed volume SHR coated vegetable seed volume

APPARATUS

The procedure is based on an expanded spouted bed of seeds (Fig. 2). A double-conical cylinder without any inserts is mounted on an airstream inlet which supplies vertically-guided hot air. Seeds are accelerated upwards centrally in the cylinder forming a fountain. By loss of pressure in the upper conical cylinder the particles float towards the cylinder walls and return to the lower conical cylinder, sliding back to the centre.

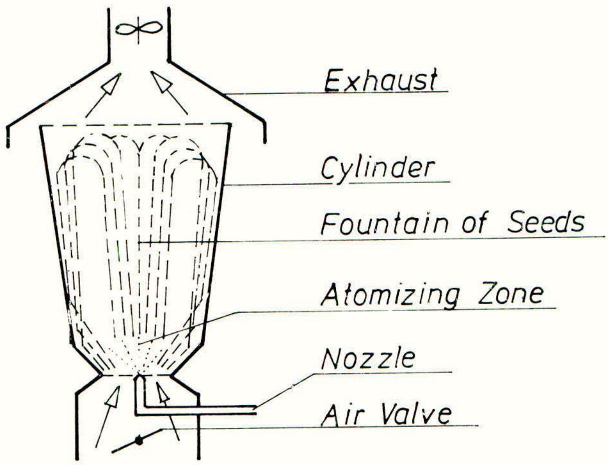


Fig. 2. SHR double-conical coating apparatus

In the zone of acceleration, the seeds absorb the spray droplets, which are coaxially atomized with defined spectrum and velocity. The coating layer is built up and the single seeds are prevented from agglomerating by rapid drying in both the upstream and the downstream.

Maximum regularity of seed recycling through the atomizing zone, constant redrying and gentle movement of particles are essential to obtain the desired uniformity of the coating on each single seed. Process specifications of seed parameters (size, specific weight, filling factor of the cylinder) and physical aspects (type of suspension, spray device, air controls) determine the constant and reproducible coating quality of all single seeds.

To prevent product losses, the top and bottom of the cylinder are equiped with sieves. The airstream is exhausted so that dust from droplets spray-drying and particle movement can be eliminated by suction.

TREATMENT

Batch and semi-continuous units have been developed with seed capacities ranging from 50 grams per batch up to several hundred kilograms per hour.

In addition to the processing units, careful preparation of the aqueous suspension is a basic requirement of application homogeneity. Inert layer-forming materials, formulation ingredients and binders, fungicides, insecticides, growth regulators and dyes are mixed in pre-determined quantities and homogenized by special machinery.

Process precision is achieved by accurate grading of seeds and suspension and by automatic remote control of hot air and pump flow rates; monitoring of dosage and constant low temperature regimes can also be achieved.

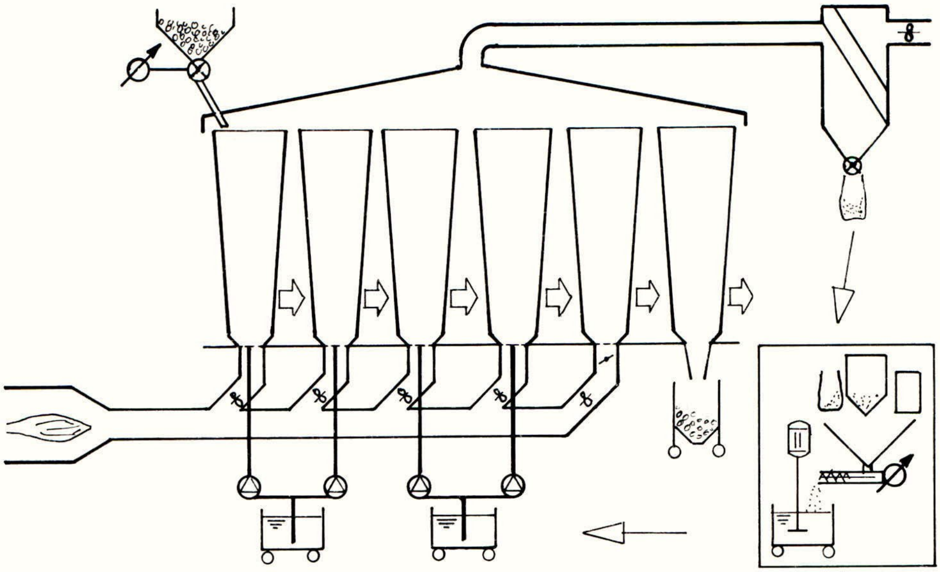


Fig. 3. SHR semi-continuous coating unit

For processing larger lots of seeds, a semi-continuous coating unit has been designed (Fig. 3). Cylinders are mounted on a turntable above several hot air and atomizing positions. From feeding at the first step until discharge after one full revolution the cylinders are guided sequentially to each position where, under the same conditions used for the batch process, different compositions of coating material are applied. Thus various layers and deposits of active or inert material can be applied to the seed. Finally, fluid bed drying is installed to eliminate residual surface humidity thereby assuring safe storage conditions.

Complete plant design includes clean and insulated building conditions, a trap system for products and operators, fresh air exchange and periodical sampling to ensure that hygiene and environmental standards are maintained. Contaminated air is filtered and particles are recycled to the suspension. Rinsing water from the mixer, pumps and nozzles is also recycled, so that contaminated waste is kept to a minimum.

QUALITY CONTROL AND ANALYSIS

An integrated system of quality assurance has been designed to ensure that all specifications of the process meet the initial targets of product quality. This entails monitoring of treatment parameters and documentation, product sampling with statistical tests of coating uniformity, dust abrasion percentage, residue water content, initial germination and shelf-life as well as loading analysis of chemicals.

For loading analysis, tlc was found to be the most suitable and economical technique. Representative samples of seed lots, or single seeds, are extracted with solvents specific to the target chemicals and aliquots transferred to special tlc plates. After separation with appropriate solvents, the concentrations of chemicals are determined by densitometric scanning and comparison with analytical standards. Because a single seed may contain several micrograms of a broad range of pesticides, including fungicide-insecticide mixtures, reliable and versatile separation techniques are essential. Several separations of a single sample may be necessary to ensure adequate isolation and uv-detection. Pesticide concentrations in the low nanogram range can be detected and evaluated. Analytical accuracy during sample-handling and extraction (Soxhlet extractor) and the determinative procedures (tlc-spotter, densitometer/ uv-scanner) should not exceed $\pm$ 5% cv. Comparison of samples evaluated by other analytical methods such as glc and hplc is arranged periodically at neutral laboratories and institutes.

Accurate dosing of individual seeds is essential if optimum protection is to be achieved and phytotoxicity and costs minimised. However, a bulk treatment, with millions of seeds treated simultaneously, entails many different seed sizes and shapes encountering a large number and size range of spray droplets. Although suitable process parameters will minimise the final loading deviations from seed to seed, certain ranges are inevitable. Fig 4. shows an example of a distribution of thiram loading between single carrot seeds. Of particular interest is any fungicide or insecticide with narrow limitations between inefficacy and phytotoxicity. These chemicals are tested statistically in laboratory, glasshouse and field experiments. The optimal loading range is also influenced by observed deposition and release effects.

However, the development of technique, process parameters as accelerated seed recycle and longer spraying sequences have improved these distribution characteristics, expressed as mathematical standard deviation from the desired dosing average. Optimum distribution between single seeds can be achieved (Fig. 5) by, for example, prolonging the treatment process. Of course, production economy and product price will set some limits.

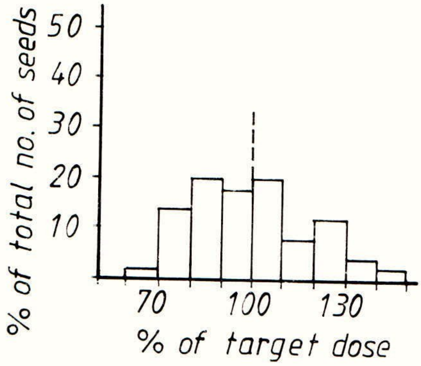


Fig. 4. Distribution of thiram between single film-coated carrot seeds. Mean loading = 100.3% of target ± sd 19.5%

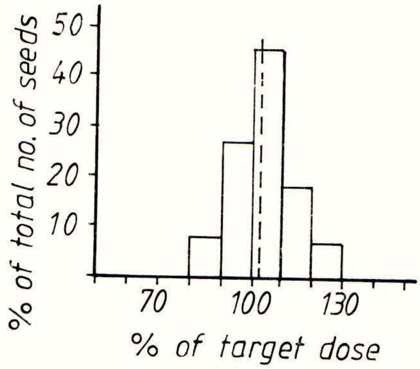


Fig. 5. Distribution of thiram between single film-coated onion seeds. Mean loading = 104.3% of target ± sd 10.2%

SEED AND PLANT PROTECTION

The application of fungicides and insecticides to seed is becoming an increasingly important way of protecting seeds and plants from diseases and insect pests, since protection quality is maintained more economically while, at the same time, environmental risks are reduced. Little is known, however, of the availability of these protectants during the period of plant growth.

Ideally, most of the applied pesticides should still be available when pest attacks are most severe. In this respect, fungicides applied to control seed- or soil-borne diseases should not present problems. Difficulties may arise with insect pest attacks, however, the timing and intensity of which can vary considerably. The approach to insect pest control, therefore, may require that seeds are loaded with the maximum possible dose of an insecticide which is targetted towards specific insects and the expected period of their attacks. Full appreciation of physico-chemical characteristics such as vapour pressure and systemic properties as well as release patterns resulting from micro-encapsulation or chemical derivations is essential for optimum performance.

Release patterns have been studied using a water-soluble insecticide (Carbofuran 500 SC of Bayer AG) filmcoated on to pelleted beet. Similar data have been obtained from field experiments by residue analysis of pellets and surrounding soil sampled at intervals after sowing. Fig. 6. shows some releases measured, with a marked increase after very wet conditions. Performance against insect pests has yet to be assessed.

A promising benefit is expected from insecticide combinations applied to seeds. Systemic insecticides (Carbofuran of Bayer AG or Furathiocarb of Ciba-Geigy) combined with a synthetic pyrethroid on pelleted beet seed gave the most encouraging results in recent years. Protection against soil- and surface-active insects was achieved for up to 8-12 weeks after sowing.

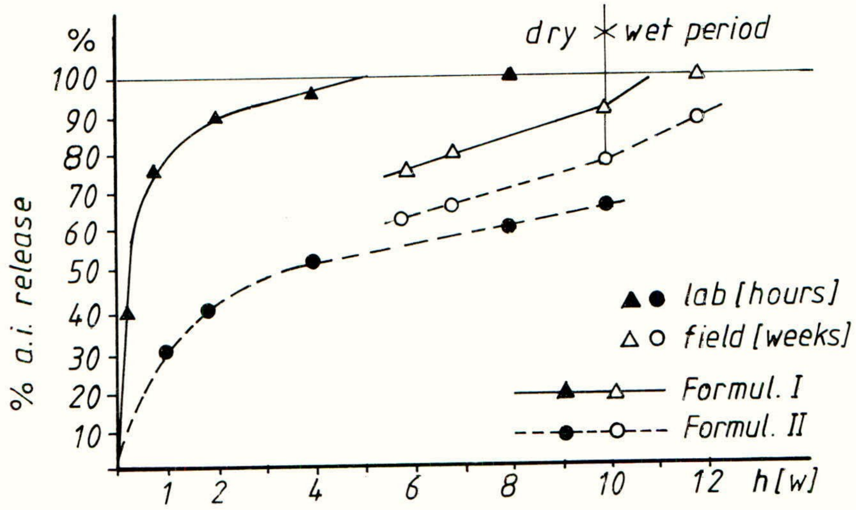


Fig. 6. Release rates of 2 formulations of Carbofuran (Bayer AG) from pelleted sugar beet seed (SUET field trials 1983)

CONCLUSIONS

The application of fungicides and insecticides to seeds by coating has opened promising chances in the field of quality, economy and ecology of chemical seed and plant protection. Besides intensive development of chemicals and formulations, seeds coated with these products are tested thoroughly in collaboration with institutes, seed and processing companies and growers to verify the new approaches.

The tecnical standard of modern coating processes ensures optimum product quality. Accurate loading of single seeds with safe processing and handling is essential. Analysis of chemicals gives proof of this quality and permits more detailed judgement of hypotheses and development.

FURATHIOCARB SEEDCOATINGS: POTENTIAL REPLACEMENTS FOR TOPICAL PESTICIDE APPLICATIONS

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ABSTRACT

Furathiocarb seedcoatings were applied using a polymer coating technique. The following crop/pest combinations were investigated: stubble turnip - Delia radicum, oilseed rape - Psylloides chrysocephala, field beans - Sitona lineatus and peas - Thrips angusticeps. The effectiveness of furathiocarb against these pests is described. Results are discussed with reference to current commercial control measures, treatment thresholds and desirability of reducing overall pesticide inputs.

INTRODUCTION

Since the introduction of the organochlorine insecticides in the 1940s, insecticidal seed treatments have been used to control a range of establishment pests of arable crops (Way, 1961). Commercially these treatments were applied as dry powders or slurrys, such application methods being subject to a number of disadvantages; they are inaccurate in terms of overall seed loading and individual seed-to-seed loading, they are liable to loss through flaking or adhesion to the container, they are difficult to apply at a dose high enough to be effective, particularly to small seeds (Jeffs,1973) and the treatments may present some hazard to both the applicator and the end user. There are several possible solutions to these problems including seed pelleting and seed coating (Halmer,1986).

Early attempts at improving seed loading capacity and the adhesive quality of treatments, depended on the addition of organic stickers such as methyl cellulose (Bardner,1961) and vegetable oil emulsions (Jeffs,1973) but, although beneficial, such treatments were still applied using rather inaccurate conventional application equipment. In the early 1980's several attempts were made to provide a machinery + sticker (seedcoating) system for the application of pesticides to seeds (Halmer,1986). A number of application systems have now been tested including film-coating (Maude & Suett,1986; T. Dennis pers. comm.; Baughan, Biddle, Blackett & Toms,1985) and incrustation (Strona & Dindorogo,1983). The field testing of these treatments against several insect pests has been reported (Baughan & Toms, 1984; Salter & Smith,1986; Thompson & Suett,1982).

This research paper is an attempt to demonstrate the efficacy of furathiocarb (Bachmann & Drabek,1981) when applied as a film-coating treatment to a range of seeds relative to topical pesticide applications.

MATERIALS AND METHODS

Chemicals used

Seed treatments

Promet 50DS	: containing furathiocarb 50% w/w
Lindane 80WP	: containing gamma-HCH 80% w/w
Ficam 80WP	: containing bendiocarb 80% w/w

Soil treatments

Campbells Phorate 10G: containing phorate 10% w/w

Application methods

Polymer coating treatments (SCT) were applied using a spouted bed polymer coating machine at Germains (UK) Ltd. of Kings Lynn, and supplied courtesy of Seedcote Systems Ltd., Thetford.

Phorate granules, where used, were combine drilled with the seed.

Seed loadings

Seed loading analysis was carried out on a range of treatments (100 g seed/sample). Chemical loadings fell within the range 86-108% of the target dose.

Trials details

The data selected for publication in this paper is extracted from an extensive trials programme, carried out over a number of seasons. Specific trials details are given in Table 1.

Assessment methods

Cabbage stem flea beetle, *Psylloides chrysocephala*, trials 1 and 2

This pest was assessed by dissecting whole plants and counting the number of flea beetle larvae per plant, with a sample size of 20 plants/plot.

Cabbage root fly, *Delia radicum*, trial 3

Cabbage root fly attack was assessed using the root damage index method described by Rolfe (1969). The sample size was 20 plants/plot.

Sitona weevil, *Sitona lineatus*, trials 4 and 5

Bean roots were sampled using a 10 cm diameter soil corer to a depth of 15 cm. Five root cores were sampled per plot. Samples were then placed into a saline solution and agitated until the weevil larvae floated free of the soil when they were counted. Plots were harvested using a Claas Compact combine harvester, the yield being given as weight of dried beans at normal maturity.

Field thrips, *Thrips angusticeps*, trial 6

Thrips were assessed by counting the number of insects per plant with a sample size of eight plants/plot. Plots were harvested using a Claas Compact combine harvester. Yield is given as weight of dry peas at normal maturity.

TABLE 1

Site details: individual trial details

Trial No.	Location	Crop/Pest	Cultivar	Drilling Date	Soil* Type	Previous Crop	Plot Size	No. of Replicates
1	Saxon Street Suffolk	Oilseed rape <u>Brassica napus</u>	Bienvenu	04.09.86	CL	Winter barley	1.5 x 6.0 m	4
2	Hare Street Herts	Oilseed rape <u>Brassica napus</u>	Bienvenu	08.09.86	C	Winter wheat	1.5 x 6.0 m	4
3	Whittlesford Cambs	Stubble turnip <u>Brassica rapa</u>	Barkant	03.07.86	SL	Winter barley	1.5 x 6.0 m	3
4	Whittlesford Cambs	Spring field beans <u>Vicia fabae</u>	Maris Bead	31.03.87	SL	Spring barley	1.5 x 12.0 m	5
5	Elmdon Essex	Spring field beans <u>Vicia fabae</u>	Maris Bead	21.04.87	CL	Winter barley	1.5 x 12.0 m	5
6	Whittlesford Cambs	Combining peas <u>Pisum sativum</u>	Countess	31.03.87	SL	Spring barley	1.5 x 12.0 m	5

Trials were planted using a Hege plot drill. Each trial was of a randomised complete block design.

*CL = clay loam, C = clay, SL = sandy loam

RESULTS

Cabbage stem flea beetle

The results (Table 2) show that the higher rate of furathiocarb gave a significant reduction in the number of larvae per stem on both sites. The lower rate of furathiocarb reduced pest numbers significantly on trial 2 and gave a substantial decrease on trial 1. Gamma-HCH also reduced pest numbers by not significantly so. On trial 2 the higher rate of furathiocarb was significantly better than the gamma-HCH standard.

TABLE 2

Performance against cabbage stem flea beetle

Treatment	Application Method	Dose g a.i./ kg seed	No. cabbage stem flea beetle larvae/plant		
			Trial 1	Trial 2	Mean
untreated	-	-	0.55	1.05	0.80
gamma-HCH	SCT	15	0.41	0.70	0.56
furathiocarb	SCT	25	0.36	0.22	0.29
furathiocarb	SCT	50	0.27	0.05	0.16
Multiple comparison, Tukey's test LSD p = 0.05			0.235	0.461	
Assessed (days after drilling)			198	155	

Cabbage root fly

The results in Table 3 indicate that although the furathiocarb seedcoating did not give a commercial level of cabbage root fly control, it nevertheless reduced the root damage index substantially. The furathiocarb seedcoating treatment was superior to gamma-HCH in this respect.

TABLE 3

Performance against cabbage root fly

Treatment	Application Method	Dose g a.i./ kg seed	Root Damage Index
untreated	-	-	29.7
gamma-HCH	SCT	15	22.2
furathiocarb	SCT	25	16.1
LSD p = 0.05			nsd
Assessed (days after drilling)			68

Sitona weevil on field beans

The results of the weevil larvae counts are given in Table 4. Furathiocarb seedcoatings at 4 or 8 g a.i./kg seed (effective rates of 100 and 200 g a.i./ha, at a seed rate of 250 kg/ha) were as effective as the phorate granule treatment for control of this pest. Yield data also given in Table 4 shows that the seed coatings and the phorate treatment improved yield considerably but differences were not statistically significant.

TABLE 4

Control of Sitona weevil and yield in t/ha

Treatment	Application Method	Dose g a.i./ kg seed	No. Sitona weevil larvae/5 plants Trial 4	No. Sitona weevil larvae/5 plants Trial 5	Yield Trial 4 (t/ha)
untreated	-	-	2.0	5.2	2.6
phorate*	G		0.2	0.4	3.3
furathiocarb	SCT	0.4	0.2	1.0	2.9
furathiocarb	SCT	0.8	0.2	0.4	2.9
furathiocarb	SCT	1.4	0.0	0.8	3.3
Multiple comparison, Tukey's test LSD p = 0.05			nsd	3.961	nsd
Assessed (days after drilling)			119	153	

*1.7 kg a.i./ha

Field thrips on peas

This trial suffered a very heavy attack of field thrips with 7.2 thrips/plant in untreated plots, (Table 5). Furathiocarb and bendiocarb seedcoating treatments significantly reduced the number of thrips per plant.

The yield results showed that treatment with furathiocarb or bendiocarb gave a substantial benefit (c. 30% increase) although not statistically different from untreated.

TABLE 5

Control of field thrips and yield in t/ha

Treatment	Application Method	Dose g a.i./ kg seed	No. field thrips/plant (8 plants/ plot)	Yield (t/ha)
untreated	-	-	7.2	3.23
bendiocarb	SCT	2	0.7	4.12
furathiocarb	SCT	2	0.3	4.25
furathiocarb	SCT	4	0.1	4.13
Multiple comparison, Tukey's test LSD p = 0.05			2.68	nsd
Assessed (days after drilling)			56	141

DISCUSSION

The results of this trial series demonstrate the potential of the seedcoating application system and the versatility of furathiocarb as a seedcoating treatment. The main advantages of seedcoating over conventional application systems are listed below:

1. They have potential to reduce the need to apply field treatments, reducing pest numbers to below economic treatment thresholds as evidenced by the control of thrips on peas and cabbage stem flea beetle on rape.

2. They can reduce the overall rate of pesticide required to achieve the desired effect, as demonstrated by the control of Sitona weevil on beans with 100 or 200 g a.i./ha applied as a seed treatment as opposed to 1700 g a.i./ha of phorate as a granule.

3. They are site specific treatments with much less risk of adverse effects against non-target organisms.

4. They give profitable control of insect pests not previously thought of as economically important (e.g. Sitona weevil on peas, Salter & Smith, 1986).

Even in cases where the seedcoating treatment gives incomplete pest control, as was the case with cabbage root fly, the effect is still economically valuable e.g. as the first part of an insecticide programme to high value crops; or as a complete programme to ensure adequate crop establishment on low value fodder crops, where crop quality is of little importance; or for short term crops such as radish; or in combination with partially resistant cultivars.

Future trials work will concentrate on demonstrating the value of these seedcoating systems in a commercial cropping programme where produce quality and cost efficiency is at a premium. The work will also evaluate the commercial acceptability of these treatments which are more pleasant and safer to use than conventional seed treatments and have the capacity for increased flexibility e.g. varying pesticides in the treatment mixture at application, including micro-nutrients, dormancy breakers or even biocontrol agents.

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CALCIUM PEROXIDE AS A SEED COATING TO ALLEVIATE STRESSES ON CROP PLANTS

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ABSTRACT

The responses of white clover, lettuce and tomato seedlings to excessive moisture was studied by subjecting the seeds and young plants to temporary waterlogging in a glasshouse environment. The results of significantly reduced emergence and seedling growth clearly indicated that all three crop plants were very sensitive to temporary waterlogging. These adverse effects of excessive moisture were alleviated by coating the seed of the three species with calcium peroxide. This oxygenating agent had little effect in enhancing or reducing crop plant establishment when the compost was not waterlogged.

The establishment of white clover plants sown at an upland site, which experienced water tables close to ground level, was also improved by coating the seed with calcium peroxide.

INTRODUCTION

Excessive soil moisture displaces air and slows oxygen diffusion through the soil. A deficiency of oxygen (anoxia) in waterlogged soils has a profound effect on crop production, its effects on crop plants being numerous and complex (Langan _et al_. 1986). In particular, the establishment of agronomically important crops is severely reduced when the soil approaches saturation with water (Drew,1983). Poor emergence of seedlings from water saturated soils has been attributed to reduced oxygen diffusion rates in the seed environments and hence to a reduction in the supply of oxygen to the seed and developing seedlings (Trought & Drew,1980). These researchers found that waterlogging of established seedlings adversely affected the water and nutrient contents of wheat shoots and attributed these effects to poor ion uptake and transport to roots which was probably caused by a low supply of oxygen to the roots.

Jackson (1983) has reviewed a variety of methods for relieving oxygen deficiency in saturated soils, one of which was the use of inorganic peroxides to supply oxygen. Inorganic peroxides have a high stability when dry but slowly hydrolyse to release oxygen when wet (Baker & Hatton, 1987). As seed coatings, peroxides supply oxygen to seeds and seedlings early in growth when the crops are most susceptible to anoxia. Calcium peroxide (CaO_2) formulations for seed coating are used commercially in Japan and the Philippines for seeding rice directly into flooded paddies (Kurosawa, 1976) and have commercial potential in the U.S.A. (Hatton & Baker, 1987). Langan et al. (1986) have reported the beneficial effects of CaO_2 on several crop plants. This paper examines the response of an important forage legume, white clover, and two horticultural crop plants to calcium peroxide.

MATERIALS AND METHODS

Glasshouse experiments

These experiments were done in a heated glasshouse, providing a minimum temperature of 10°C without supplementary lighting (except for the tomato experiment) at the Agricultural Biology Field Station, near Wylam in south Northumberland. In order to coat the seed with CaO_2 seeds were first treated with a binding agent on to which the calcium formulations were applied. The aqueous seed coating incorporated a hydrophilic binding agent whilst the non-aqueous seed coating, which was used only in the white clover seed, incorporated a non-hydrophilic binding agent. The aqueous seed coating caused phytotoxicity effects on white clover but not on lettuce or tomato seedlings. The formulations were applied by Interox Chemicals on a weight of chemical to weight of seed basis. The calcium peroxide formulation contained 60% CaO_2 and 40% of other products. In this paper, the amount of calcium peroxide on the seeds represented the weight of active ingredient of the chemical relative to the weight of the seed.

Seeds of the white clover cultivar S.184, the lettuce cultivar Webbs Wonderful and the tomato cultivar Moneymaker were placed 1cm below the surface of the soil media contained in 7.5cm diameter plastic pots. Ten seeds were sown in the central region of each pot with the exception of tomatoes where three seeds were sown. Seeds were not sown around the periphery of the pots because of the possibility of oxygen diffusion from the air in a vertical direction down the inside surface of the pots. There were ten replicates of each pot per treatment. The seed was sown in John Innes No.2 compost which was not steam sterilized. Previous experimentation had shown that the optimum seed treatments were 300g aqueous CaO_2/kg seed for the lettuce and tomato seeds and 300g non-aqueous CaO_2/kg seed for the white clover seed. Each seed treatment was subjected to two watering regimes - liberally watered when necessary but not waterlogged, and waterlogged for varying lengths of time commencing one, two or three days after sowing. The compost was waterlogged by placing the pots in water contained in plastic trays (370cm x 220cm x 60cm depth), and adjusting the level of the water in the trays to the level of the compost in the pots (tomato and white clover only). The lettuce seeds were extremely sensitive to waterlogging and thus the level of the water was restricted to half the depth of compost in the pots.

The number of seedlings which emerged was recorded at regular intervals. All the seedlings were cut at the surface of the compost. After removal of any contaminating compost, the harvested shoots were dried at 90°C in an oven for 24h and then weighed. However, six tomato seedlings were retained at random from each treatment, potted on twice into larger pots, fertilized and allowed to set flowers and fruit on three trusses. The numbers of flowers and fruit together with the fresh weight of the fruit were recorded.

Field experiment

In a small trial, uncoated white clover seed and seed coated with 30% non-aqueous CaO_2 were sown in the summer of 1984 at an upland site. The site was located at the Redesdale Experimental Husbandry Farm on a brown earth soil situated at 230 metres above sea level in north Northumberland. The site received a compound fertilizer of 60kg P ha^{-1} and 60kg K ha^{-1}, and also lime to correct the pH to 6.2. The drainage was impeded with some surface run off of water on to the site from nearby poorly drained pasture growing on peat and clay. All the seed was sown by hand in small plots consisting of four drills 10cm apart and 1m in length. Hand sowing was necessary to ensure that the same number of seed was sown in each plot. Fifty seeds were placed at 2cm spacings within each drill at a depth of approximately 1.5cm below the soil surface. Each treatment was replicated five times. Counts were recorded of the number of plants in the central two drills of each plot. The shoots of all plants in the sample area were harvested on four occasions (28 May, 9 July, 20 August, 8 October) in the following year by cutting the plants at a distance of 2cm above the level of the soil. After removal of contaminating soil, the shoots were dried in an oven for 24h and then weighed.

RESULTS

Lettuce

Short duration waterlogging, where half the depth of compost was inundated with water one day after sowing, produced a marked reduction in plant emergence which was completely alleviated by coating the seed with 30% aqueous CaO_2 (Table 1).

Temporary waterlogging caused a severe reduction in the growth of lettuce seedlings which developed from uncoated seed and survived the water stress. Coating the seed with CaO_2 significantly increased the dry weight of lettuce shoots which developed under waterlogging and were harvested 22 days after sowing (Table 1). Early seedling growth was not significantly affected by the CaO_2 coating compared with uncoated seed when the compost was not waterlogged.

TABLE 1

Emergence (%) and mean shoot dry weights (mg) of lettuce seedlings from waterlogged and non-waterlogged compost

	Not waterlogged	Waterlogged for 1day	2 days
Emergence			
Uncoated seed	93	68	66
Coated seed	88	92	93
Mean shoot dry weights			
Uncoated seed	541	301	121
Coated seed	487	446	288
LSD (p = 0.05)	NS	81	35

Tomato

Complete waterlogging of the compost for 2 days reduced seedling emergence, shoot growth and fresh fruit yield of tomato plants from uncoated seed (Table 2).

Not only did coating the seed with 30% CaO_2 completely alleviate the adverse effects on waterlogging tomato seeds, it also created larger numbers and thus total weight of fresh fruit compared with uncoated, non-waterlogged (i.e. control) plants (Table 2).

White clover

Waterlogging the uncoated seed of this legume for 3 days in a glasshouse environment, commencing 2 days after sowing, caused a marked reduction in plant emergence and in the growth of those seedlings which did emerge after water stressing (Table 3).

TABLE 2

Emergence (%), mean shoot dry weight (mg), mean number of fruits (per plant) and mean fresh fruit weights (kg/plant) of tomato plants from waterlogged and non-waterlogged compost

	Not waterlogged	Waterlogged for 2 days	LSD (p=0.05)
<u>Emergence</u>			
Uncoated seed	90	20	
Coated seed	95	88	
<u>Mean shoot dry weight</u> (21 days after sowing)			
Uncoated seed	36.0	21.5	8.7
Coated seed	38.5	44.3	NS
LSD (p = 0.05)	NS	9.3	
<u>No. fruits</u> (5 months after sowing)			
Uncoated seed	10	11	
Coated seed	*	14	
<u>Fresh fruit weight</u> (5 months after sowing)			
Uncoated seed	0.78	0.66	0.055
Coated seed	*	1.03	
LSD (p = 0.05)		0.08	

* not grown and recorded because of lack of glasshouse space

TABLE 3

Effect of waterlogging and CaO_2 coating on the emergence (%) and seedling growth (mg dry weight) of white clover in a glasshouse environment.

	Not waterlogged	Waterlogged for 3 days
<u>Emergence</u>		
Uncoated seed	80	31
Coated seed	83	61
<u>Mean shoot dry weight</u> (after 30 days after sowing)		
Uncoated seed	12.6	5.2
Coated seed	11.3	10.8
LSD (p = 0.05)	NS	3.0

Calcium peroxide coating did partially alleviate the adverse emergence and shoot dry weight effects of waterlogging in a controlled environment (Table 3).

In the upland field trial, CaO_2 seed coating also improved the emergence and shoot growth of white clover when sown in summer 1984 and harvested during the following year (Table 4).

TABLE 4

Plant counts and shoot dry weights (g) from $0.2m^2$ field plots of white clover with and without CaO_2 seed coating

	Plant counts 7.6.84	Plant counts 28.6.84	Total shoot dry weights (4 harvests in 1985)
Seed not coated	80.3 ± 3.49	80.3 ± 5.11	560.0
Seed coated with 30% CaO_2	93.0 ± 7.32	97.5 ± 5.59	695.3
LSD (p = 0.05)			69.1

DISCUSSION

The results of all the experiments described in this paper strongly suggest that CaO_2 can enhance the establishment of lettuce, tomato and white clover plants growing in soil media which becomes temporarily waterlogged after sowing. It is unlikely that the advantage of the chemical is in supplying calcium to the establishing plants since this has not been reported in previous experimentation (Ollerenshaw,1985), the quantity of calcium contained in the coating is very small and the soil media used contained ample supplies of available calcium. Calcium peroxide may supply oxygen to the seed to improve emergence and early growth as in rice (Ogawa & Ota,1973), sugar beet (Gallebant et al. 1982), grass (Naylor & Prentice, 1986), barley and wheat (Sladdin & Lynch,1983) and cowpea and soyabean (Ogunremi et al. 1981). The chemical may also supply oxygen to the developing roots to ensure adequate nutrient uptake for rapid root and shoot establishment (Ollerenshaw,1985).

In previous studies, peroxides were postulated to have beneficial effects because of a sterilizing action in reducing the mortality of emerged seedlings (Marshall & Naylor,1984). In the tomato experiments several seedlings arising from uncoated seed did die as a result of damping off disease. No such deaths of tomato seedlings were recorded of plants grown from seed coated with CaO_2. However, many commercial crop plant seed are usually supplied with a combined insecticide/fungicide seed dressing and so any neutralising of phytotoxic acids and anti-fungal activity of calcium peroxide may be relatively unimportant (Thomson *et al*.1983). Currently though, it is not standard practice to apply insecticides or fungicides to the seed of lettuce, tomatoes or white clover. Hence these crops may particularly benefit in improving emergence under wet soil conditions and/or in the presence of pests and diseases from the peroxide seed coatings. White clover is a very important herbage legume in pastures and hence a satisfactory establishment in competition with grasses is essential. Further, the seed of this crop plant, together with vegetable seeds, are generally expensive. In addition, lettuce seed grown under hot conditions has a tendency to dormancy, so cooling off is effected by irrigation but farmers frequently overtreat to waterlogging conditions with consequent loss of emergence (Leaver, J.P., personal communication).

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