3.
Innovations in Application Methods

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USING THE SEED AS A CHEMICAL CARRIER

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ABSTRACT

Seed treatments are a very effective and efficient method of applying chemicals to a crop. Field trials have shown that in order to control all three of the important soil and seed-borne diseases of peas it is necessary to use a seed coating process, as it was impossible to stick sufficient material onto the seed using standard seed dressing techniques. Using the coating process it was possible to include an insecticide in the seed dressing which gave excellent control of the pea and bean weevil (Sitona lineatus). Previously Sitona control had only been possible with costly sprays or phorate granule treatments.

INTRODUCTION

Each year the large chemical companies spend many millions of dollars developing new chemicals for agriculture. These new herbicides, fungicides and insecticides are safer than their forerunners, more active and more selective.

However, despite these advances in chemistry, the process of applying these chemicals to the crops has hardly changed in the last 50 years. The vast majority of these chemicals are simply mixed with water and sprayed through a nozzle to produce small droplets which land on the crop. It is widely acknowledged that this process is very inefficient as only a very small proportion of the chemical actually reaches the target site. The remainder is thus wasted.

The work presented in this paper is from a series of trials conducted over three years on the development of a new seed treatment for peas. Seed treatments have been widely used for the last forty years to control some seed-borne diseases and the 'seedling damping-off' diseases with materials such as mercury, thiram, captan and drazoxolon. However, the recent development of various systemic fungicides and insecticides has meant that it is now possible to control a wide range of fungal and insect pests using seed dressings. Probably the best known example is the control of powdery mildew on cereals with ethirimol and triadimenol.

Peas can be subjected to attack by a number of diseases including the 'seedling damping-off' diseases (primarily Pythium ultimum), leaf and pod spot (caused by several closely related fungi Ascochyta pisi, Mycosphaerella pinodes, Phoma medicaginis var. pinodella and downy mildew (Peronspora viciae).

The development of 'damping off' diseases, caused primarily by the soil-borne fungus Pythium ultimum, is favoured by cool, wet conditions.

Therefore, early drilled varieties suffer most from this damage and as a result the early sown crops are normally drilled at a slightly higher seed rate than those sown later. The seed and emerging seedlings can be protected, very cheaply and very effectively, from the 'damping-off' diseases by seed treatments with captan, thiram or drazoxolon.

Downy mildew (Peronspora viciae) is the most widespread and damaging fungal disease of peas grown in this country. This fungus survives as oospores in the soil for four to six years and under cool wet conditions in the Spring the emerging seedlings become infected. This either kills the seedlings immediately, greatly reducing the plant population, or the infected seedling emerges to infect neighbouring plants. Plants with the primary infection are usually pale, stunted and covered with the grey-brown mycelium of the fungus. Under humid conditions large numbers of fungal spores are released and spread by the wind to neighbouring plants. These air-borne spores can then form localised infections on the upper leaves of these plants producing the characteristic secondary infection and it can remain systemic within the plant; so that as the plant continues to develop the downy mildew will reappear on new foliage at the top of the plant. Plants with secondary infections also act as a foci to spread the disease to surrounding plants and developing pods. Therefore, under favourable environmental conditions, a field epidemic can easily occur. Seed treatments are now available commercially to control downy mildew on peas, these are based on either metalaxyl or fosetyl aluminium. These chemicals protect the emerging seedlings from the soil-borne disease preventing the development of the primary infection which in turn prevents the production of air-borne spores which spreads the disease throughout the crop.

The Ascochyta species causing leaf and pod spot and some foot rot problems, are seed-borne diseases which can be very effectively controlled with a thiabendazole based seed dressing (Biddle 1981). In this country nearly all seed stocks are tested for Ascochyta and any lots with more than approximately 5% of infected seed is either rejected or treated with a suitable seed dressing.

In addition to the various fungal diseases already mentioned, pea crops suffer from a number of insect pests which can cause severe crop losses. The pea and bean weevil (Sitona lineatus) attacks a wide range of leguminous crops and can be found in virtually all pea and bean crops. The adult weevils emerge from hibernation in the early spring and start to feed on the foliage producing the characteristic semi-circular notches in the leaf edges. In severe cases gross defoliation can take place but crops that are growing well usually tolerate leaf damage without causing severe losses. The adult weevils have also been shown to transmit Broad Bean True Mosaic Virus to field beans (Cockbain et al, 1975). However, the weevil larvae which live in the soil and burrow into the root system can cause severe damage as they feed on the nitrogen fixing root nodules which can produce a yellowing of the plants due to the lack of nitrogen. Larvae damage to the roots can also increase the incidence of fungal root infections.

Currently pea and bean weevils are controlled by either phorate or aldicarb granule treatments or using a triazophos or pyrethroid based spray applied to the foliage.

When these studies were initiated, in 1982, treatments were available to control either downy mildew and the 'damping-off' diseases or the 'damping-off' diseases plus Ascochyta. The initial aim of this research was, therefore, to produce a '3-way' seed treatment for peas, to control all of the fungal diseases of peas. The authors felt that such a mixture would be very useful as it would enable a downy mildew treatment to be applied to Ascochyta infected seed without having to 'double dress' the seed which could also incur various problems.

1. Second run through the machinery is time consuming and inconvenient.

2. The initial treatment may be partially knocked off.

3. The material applied second may not stick to the first dressing.

4. Seed may be damaged by excessive handling.

5. The two treatments may not be compatible.

6. A double dose of captan is being applied.

MATERIALS AND METHODS

Chemical Used

H101	-	Captan (0.5g a.i./kg seed) + Thiabendazole (0.375g a.i./kg seed) applied at 1.375g /kg seed.
H102	-	Thiabendazole (0.375g a.i./kg seed) + Fosetyl Aluminium (1.54g a.i./kg seed) applied at 2.55g/kg seed.
FR999/1	-	Captan (0.5g a.i./kg seed) + Fosetyl Aluminium (1.54 g a.i./kg seed) applied at 2.5g/kg seed.
H103	-	Captan (0.5g a.i./kg seed) + Thiabendazole (0.375g a.i./kg seed) + Fosetyl Aluminium (1.54g a.i./kg seed) applied at 3.123g/kg seed.
Captan	-	Captan (0.5g a.i./kg seed) applied at 1.0g/kg seed.
H104	-	H103 + Bromophos (2.0g a.i./kg seed) applied in a seed coating.
H105	-	H103 + Bendiocarb (2.0g a.i./kg seed) applied in a seed coating.

Phorate granules (10% w/w) were broadcast at the rate of 22.4 kg/ha (2.24 kg a.i./ha and then incorporated into the soil prior to drilling.

Treating the Seed

All of the seed treatments, except H104 and H105, were applied to the seed as a slurry in the laboratory and then allowed to dry in the open for at least 24 hours before drilling.

Coating Seed

In addition to applying the seed dressings as a slurry preparation many of the different formulations were applied to the seed using a new form of seed coating process by Dr J Johnson of Germain's (UK) Limited.

Seed Used

Because these trials were spread over a number of years, several different varieties and different seed lots were used. All the seed used was infected with *Ascochyta*, with a minimum of 19% infected seed.

Trial Design

Each of the different trials was a replicated trial using four randomised blocks of plots, which were between 5 and 10m long by 1.5m wide.

Assessments

Field plant populations were assessed using either a 0.25m2 quadrat or by counting the number of plants per 3 foot row length; in each case the results presented are the mean of 5 counts per replicate. Disease assessments were designed to determine both the level and the severity of the disease. *Ascochyta* was assessed by determining the percentage of plants infected and by counting the number of stem or leaf lesions per plant. Downy mildew was assessed by determining the number of plants infected and the severity of the disease was measured using a severity index (DSI) based on the percentage of leaf or surface area infected as follows:-

Score	% leaf area infected
1	Up to 1%
2	1 - 5%
3	6 - 10%
4	11 - 25%
5	26 - 50%
6	Over 50%

The sum of the scores allocated was then divided by the number of plants assessed, giving a disease score index (DSI). *Sitona* damage to the foliage, caused by adult weevils, was determined by counting the number of 'notches' in each leaf. Weevil larvae numbers were assessed by disecting two inch diameter root core samples under water and counting the number of larvae found. Yields were assessed by harvesting 7.5m2 of haulm from each plot and then feeding it through either a 'Mini Vining machine' with vining pea varieties or through a 'Trials Combine' withcombining pea samples.

RESULTS

The first set of trials were set up to evaluate a '3-way' seed treatment for peas (to control the 'damping-off' diseases,*Ascochyta* and downy mildew) which was a formulated mixture of captan, thiabendazole and fosetyl aluminium applied as a slurry. This mixture was compared with a number of other 'standard' pea treatments, some of which are commercially available, which were applied at much lower doses than was required with the '3-way' dressing, H103.

TABLE 1
Germination and Disease Control Results with Sprite Seed Treated with Various Fungicide Based Formulations Applied as a Slurry.

Trial 1

	Emergence (%)	Downy Mildew (% plants infected)	Ascochyta (% plants infected)
Untreated	38	6.7	31
Captan	71	8.8	8
H101	65	16.5	0
H102	73	1.7	5.4
H103	73	7.3	0

Trial 2

	Plant Population (Plants/m2) (30.4.82)	Downy Mildew (% Plants infected)	Ascochyta (% plants infected) (17.5.84)	Yield (t/ha) (1.7.82)
Untreated	56.0	40.9	63.6	2.38
FR999/1	75.2	15.8	82.2	3.06
H102	79.2	25.6	94.8	3.06
H103	75.2	22.2	79.1	2.41

The two field trials with seed treatments applied as a slurry were set up using Sprite seed, 23% of which was infected with Ascochyta. Trial 1 was conducted at the Processors and Growers Research Organisation at Thornhaugh, the germination and disease assessments made 6 weeks after sowing. The second trial was sown on 1st April at a field site at Holbeach St Marks.

The results of the two field trials in Table 1 show the importance of using some form of seed treatment with peas, since in both cases the germination of the untreated seed was very low compared with the different lots of treated seed. In trial 1 the only treatment which gave any control of downy mildew was H102; the '3-way' mixture (H103) was no better than the captan treatment even though it contains the downy mildew fungicide, fosetyl aluminium. The very high levels of Ascochyta in the untreated plots in trial 1 suggests that the captan treatment on its own does give some control of this disease. However, the results also show that both H101 (which is a commercially available Ascochyta treatment) and H103 gave good Ascochyta control, even though the H103 treatment gave no apparent downy mildew control.

In the second series of trials neither H102 or H103 gave any control of the seed-borne disease, Ascochyta, and only FR999/1 gave any control of downy mildew. The yield results from this trial suggested that the '3-way' mixture (H103) gave virtually no yield benefit over the untreated seed, whereas the '2-way' seed dressings (FR999/1 and H102) gave an obvious increase in yield.

From this work it was concluded that the '3-way' mixture, H103, was not as effective as either H101 in controlling Ascochyta or FR999/1 in controlling downy mildew. The poor disease control was attributed to inadequate fungicide loadings on the seed. With the two '2-way' mixtures, FR999/1 and H101, only comparatively small quantities of material were required (2.5g and 1.375g per kg seed respectively) compared with 3.123g/kg of H103. The smaller quantities of material could be applied fairly easily to the seed and, moreover, the chemicals remained firmly attached to the seed surface until drilling. However, the larger quantity of H103 was often difficult to apply to the seed and the material tended to 'come off' the seed during handling and on storage. This meant that by the time the seed was sown, the loadings were very uneven so that on some seeds there was probably insufficient chemical to give adequate disease control.

The obvious solution was, therefore, to find a more suitable method of applying the chemical to the pea seed. One method which was tried was to use a seed coating process. Seed coating is a refinement of the pelleting process which has been widely used on seeds, especially sugarbeet, for nearly 20 years. With the seed coating process the amount of inert material around the seed is reduced to a minimum, so that the coated pea seed is only 1 - 2% heavier than the naked seed - although this is dependent on how much of the various chemicals, fertilizers or micronutrients are incorporated into the coating.

The coating process was, therefore, used to treat Ascochyta infected Scout seed, for the next series of replicated small plot trials, with Captan, H101 and H103. Using the coating process it was possible to apply the full dose of each of the materials evenly and accurately into the seed and, unlike the slurry treatments, the chemicals did not 'come off' the seed during handling or on storage.

The results in Table 2 show that the '3-way' mixture, H103, applied as a coating gave excellent control of both Ascochyta and downy mildew. The very high levels of Ascochyta in this trial were due largely to the cold wet conditions which prevailed throughout the Spring, as this encouraged the development of the disease. Furthermore, the heavy rains washed spores from the infected plants onto uninfected ones causing the disease to spread rapidly through the plots. This was probably also responsible for introducing the disease into the treated areas from nearby untreated plots. However, despite this cross infection between the plots which produced the very high levels of infection in all of the plots at the second assessment, both the H101 and H103 treatments gave a highly significant reduction in the number of stem and leaf lesions.

TABLE 2

Disease Control with Coated Pea Seed.

First Assessment

Treatment	no. of plants	% plants infected Ascochyta		% plants infected Downy Mildew	D.S.I. Downy Mildew	
Captan	9.17	37.45	a	56.95	0.188	a
H101	9.60	9.94	c	56.25	0.315	a
H103	12.13	6.80	c	47.67	0.118	d
	N.S.	SE = 4.43		NS	SE = 0.042	

.. Table 2 Cont'd over

TABLE 2 cont'd.
Second Assessment

Treatment	% plants infected 2% downy mildew	% plants infected Ascochyta	No. of Ascochyta Lesions/plant Stem lesions	No. of Ascochyta Lesions/plant Leaf lesions
Captan	78.8	97.4	2.8 a	11.0 a
H101	93.3	70.2	0.7 c	3.8 b
H103	73.7	84.5	0.6 c	3.14 b
	NS	NS	SE = 0.7	SE = 2.39

a & b are significantly different at P = 0.05
a & c are significantly different at P = 0.01
a & d are significantly different at P = 0.001

Scout seed (19% of which was infected with Ascochyta) coated with the three different seed treatments, captan, H101 and H103 drilled on 7th March, 1983. Plant population and disease assessments were made 12 and 16 weeks after sowing. The results are the mean of 10 x 3 foot row samples per plot. The disease score index (DSI), used to assess the severity of the downy mildew infection, is described in the Materials and Methods Section.

The cold wet conditions which favoured the establishment and spread of the Ascochyta also encouraged the development of downy mildew. Plants infected with primary downy mildew in the captan and H101 treated plots sporulated to spread the disease to previously healthy plants. Although the disease assessment results show that there was no reduction in the levels of downy mildew, the severity assessment (based on a Disease Score Index, DSI) showed that the H103 treatment reduced the severity of the disease.

The results from the replicated small plot trial do not really demonstrate the levels of Ascochyta and downy mildew control given by the H103 seed treatment applied as a coating, due to the problems of cross-infection between plots. However, large scale field trials, conducted in 1984 with one acre blocks of H103 coated seed, showed that the seed coating treatment gave excellent control of both Ascochyta and downy mildew (data not presented).

Using the seed coating process it is possible to apply much larger quantities of material onto a seed than was necessary with the '3-way' mixture, H103. Therefore, further studies were conducted to determine the feasibility of adding an insecticide to the seed coating to control the pea and bean weevil (Sitona lineatus). Work conducted by King (1981) at the Processors and Growers Research Organisation showed that Sitona could be effectively controlled by phorate granule treatments, applied to the seedbed prior to drilling, and that this produced an increase in yield.

Two different insecticides were added to the '3-way' mixture (H103) for the next series of field trials, bromophos (H104) which is a non-systemic organophosphorous insecticide of low mammalian toxicity and bendiocarb (H105) which is a broad spectrum systemic carbamate insecticide.

TABLE 3

Controlling the Pea and Bean Weevil with Insecticides Incorporated into The Seed Coatings.

Progreta

	Treatment			
	H103	H104	H105	Untreated
Plants/m2	63.3	66	64.8	42
notches/leaf	18.3	15.3	4.1	14.8
larvae/root	2.4	2.15	0.8	1.25
				SE = 0.472
yield(t/ha)	5.12	5.31	5.39	5.01
				SE = 0.4
yield(%H103)	100%	104%	105%	98%

Sprite

	Treatment			
	H103	H104	H105	Untreated
Plants/m2	67.2	59	62.2	19.8
notches/leaf	15.2	13.6	3.2	22
larvae/root	1.45	1.15	0.15	0.85
				SE = 0.358
yield(t/ha)	4.44	4.33	5.2	1.28
				SE = 0.52
yield(% H103)	100%	97.5%	117.1%	28.8%

Two varieties of peas were used for these studies, Progreta, a protein or combining pea, and Sprite, a vining pea variety. Naked or untreated seed, was used as the standard treatment. This seed was drilled into a seedbed which had been treated with phorate granules. The first Sitona assessments, of damage to the foliage, were made 7 weeks after drilling and the second assessment of larvae numbers were made 12 weeks after drilling.

The results in Table 3 show that all of the seed coating formulations improved the germination of the pea seed in the field. This was particularly evident with the vining pea variety, Sprite, as the seed was comparatively poor with a very low vigour reading. Gane & Biddle (1978) showed that when low vigour seed is sown under non-ideal conditions, such as in a cold wet seedbed, the germination is low resulting in a poor plant stand. This can be improved considerably by a seed treatment such as captan or thiram to control the 'damping-off' diseases.

The Sitona assessments (in Table 3) show that the bromophos treatment, H104, gave very poor control of both adult weevils and larvae. However, the bendiocarb treatment, H105, gave a marked reduction of both the feeding of the adults on the foliage and in the number of larvae feeding on the root nodules. This reduction in weevil damage produced a 5% increase in yield with the combining pea variety, Progreta, and a 17% increase with the vining pea variety, Sprite. These increases in yield were due solely to the insecticide component of the H105 seed coating formulation as they are compared with the '3-way' fungicide mixture, H103. The phorate granule treatment, which was incorporated into the seedbed immediately prior to drilling, gave some reduction in leaf notching and in the numbers of weevil larvae. It is difficult to draw any conclusions about the effect on the soil incorporated granular insecticide on crop yield as the plant establishment, with the untreated seed, was very poor. However, it is obvious that the phorate granule treatment was not as effective as the bendiocarb seed treatment; which was applied, together with the three fungicides, captan, thiabendazole and fosetyl aluminium, as a seed coating.

DISCUSSION

These results have shown that although chemicals are available, as seed dressings, to control the three main fungal diseases of pea, it is difficult to apply sufficient material to a pea seed, using the normal slurry treatments, to control all three diseases adequately. However, using a seed coating process it is possible to apply the chemicals evenly and accurately onto the seed so that the material does not 'come off' with handling or during storage. Field trials demonstrated that pea seed coated with a formulated mixture of captan, thiabendazole and fosetyl aluminium (H103) gave excellent control of both downy mildew and Ascochyta. Moreover, incorporating the systemic insecticide, bendiocarb, with the three fungicides in the seed coating gave much better control of the pea and bean weevil (Sitona lineatus) than a phorate granule treatment.

Seed treatments obviously cannot be used to apply all of the different types of chemical to a crop. However, using suitable systemic fungicides and insecticides, perhaps in conjunction with some form of slow release mechanism, it should be possible to reduce the number of routine sprays applied to a crop. Seed coating techniques can be used to treat a wide range of different seeds (Toms & Blackett, 1983; Blackett & Toms, 1983) and trials with coated cereal seeds are already planned.

Using seed treatments to apply chemicals to a crop is a very practical and efficient process. It is generally acknowledged that spraying chemicals onto a crop is a very wasteful process as only a fraction of the material actually reaches the target site. When chemials are applied onto the seed they are automatically placed exactly at the base of the developing plant. It is also likely that many materials are absorbed more readily through the root hairs than through the cuticle of the leaves and movement of these chemials from the roots to the whole plant is perhaps easier than passage from one leaf to the next.

The last set of trials clearly demonstrated that a small amount of chemical applied as a seed dressing can be more effective than much larger quantities of material broadcast throughout the soil. Using the seed coating approach it required only about 320 g of bendiocarb per hectare (160 kg seed/ha @ 2g bendiocarb/kg) compared with 2.24 kg of phorate per hectare. It is hoped that this approach of using coated pea seed will reduce some of the unfortunate side effects on the beneficial insect species. Lee (1983) demonstrated that large carabids and other insect predators are important in controlling weevils on pea and bean crops.

Therefore, it is expected that by carefully applying the insecticide, within a seed coating, that some aspects of biological and integrated pest control can be achieved.

ACKNOWLEDGEMENT

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FIELD TRIALS WITH THE GIROJET

M MOREL

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The Girojet is a vertically mounted centrifugal nozzle producing a 140 degree flat fan spray pattern for improved crop penetration at low volumes.

The nozzle consists of a large diameter 14cm disc which gives a band of droplet sizes ejected in the shortest trajectory to the target in the vertical plane. The disc is driven by a 12 volt electric motor with a disc speed controllable from 1100 to 4200 rev/min by means of a rheostat located on the head.

The feed tube allows liquid to flow directly onto the centre of the disc for the sheet of liquid to be evenly spread to the serrated teeth to break up into droplets.

38% of the liquid is sprayed out in a 140 degree fan, whilst the balance is recovered through a 220 degree recovery housing over the upper segment of the disc. This liquid is recycled and by means of a venturi, returned into the circuit. This keeps large volumes of liquid on the move, thus reducing the possibility of sedimentation.

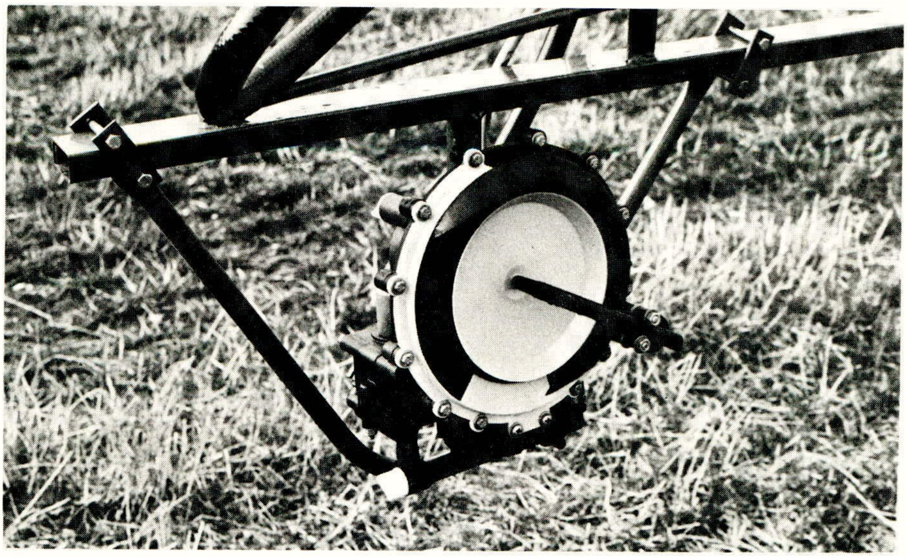


Diagram 1 - GIROJET

RESULTS IN THE FIELD

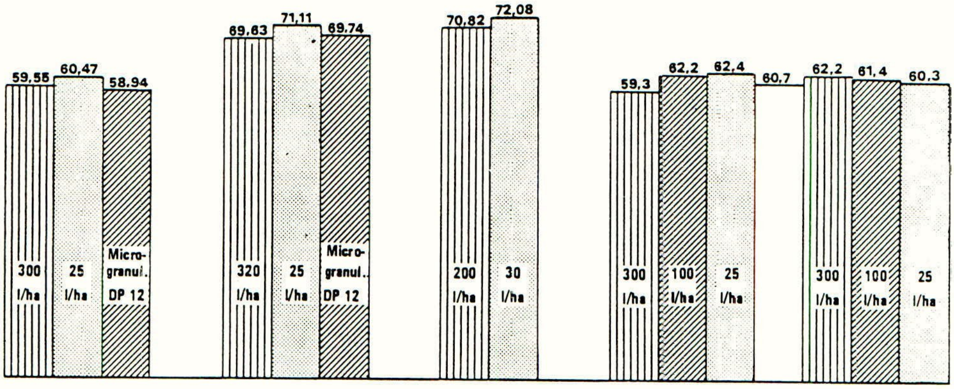
Application rates with the Girojet can be controlled from 20-40 l/ha, but our average commercial application volume is 25 l/ha. The Girojet field trials referred to, are from 25 l/ha to 40 l/ha. Trials have consisted of applying commercial products at the same stage, weather conditions, and at the same dosage rate.

Reference volumes with conventional equipment range from 120-400 l/ha.

The earlier trials (1981) were applied with 150 litre tractor-mounted unit with a 9 metre boom and 6 Girojets. All later trials were completed with a TG 412 400 litre mounted unit with a 12 metre boom and 8 Girojets, which is now the commercial sprayer specification.

Herbicides

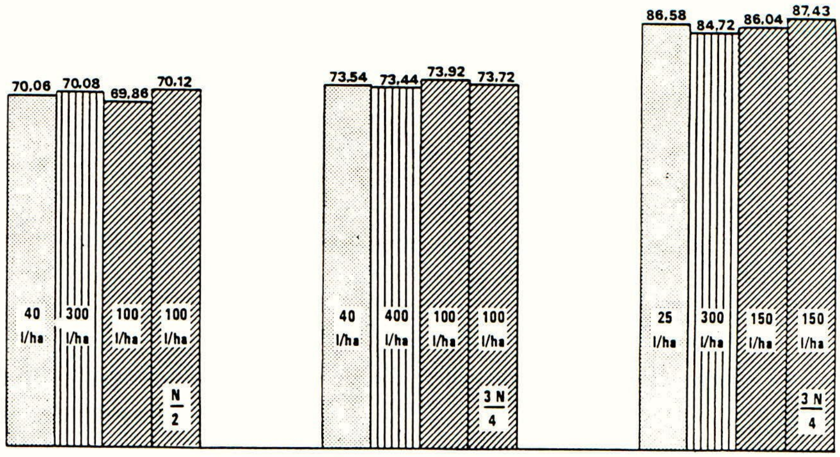
Pre-drilling incorporated chemicals have not revealed any differences in control effectiveness or plant toxicity between conventional application volumes and the 25 l/ha volume with the GIROJET.



Trial	1101 1102	1103	← A → ← B → 1105
Crop	Fidel (W Wheat)	Pirate (W Barley)	Fidel (W Wheat)
Product	- chlortoluron (Dicurane) 3.3kg/ha chlortoluron (Dicurane granules) 13kg/ha	Isoproturon/ nebron (Prodix) 4.5kg/ha	(A) - CH25 (Winner) 4kg/ha (B) - Nebron/Nitrofen (Herbalt) 7kg/ha

Girojet 25-40 l/ha
Conventional 300-400 l/ha
Conventional 100 l/ha

TABLE A - AUTUMN HERBICIDES - PRE-EMERGENCE *



Trial:	1201	1202	1203
Crop:	Arminda (W Wheat)	Arminda (W Wheat)	Fidel (W Wheat)
Product:	Isoproturon (Tolkan) 5.5 l/ha	Isoproturon + mecoprop + ioxynil (Belgran 3 l/ha) (Certrol 0.5 l/ha)	Isoproturon + mecoprop + ioxynil (Belgran 4 l/ha + MCPP 0.7 l/ha + CCC 1.5 l/ha

Girojet 25-40 l/ha
Conventional 300-400 l/ha
Conventional 100-150 l/ha

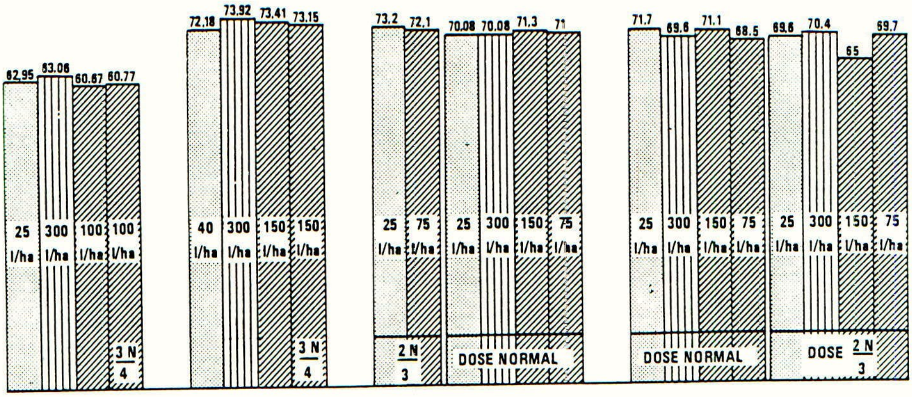
TABLE B - SPRING HERBICIDES - POST-EMERGENCE *

GROWTH REGULATORS

CETA in Mouy carried out several precise tests to demonstrate the equivalent effectiveness of the various treatments.

The highest concentrations did not prove to be toxic to plants and the 25 l/ha treatments applied using the Girojet nozzle were at least as good, if not better, than some of the references.

* Results of CETA Mouy (60) and GDA Creil-Neuilly (60)



Trial:	1301	1302	1303	1304
Crop:	Sonja (W Barley)	Fidel (W Wheat)	Fidel (W Wheat)	Fidel (W Wheat)
Product:	Ethephan (Etheverse) 1 l/ha	CCC 2 l/ha	CCC 1.8 l/ha	CCC 1.8 l/ha

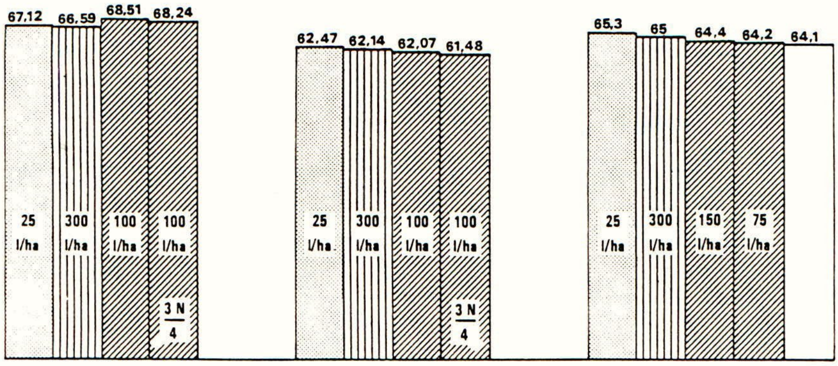
Girojet 25-40 l/ha
Conventional 300 l/ha
Conventional 75-150 l/ha

TABLE C - GROWTH REGULATORS - CETA Mouy (60)

FUNGICIDES

Tests carried out in conjunction with the various bodies - (CETA in l'Aunette, CETA in Soissons, GDA in Creil-Neuilly, CETA in La Vallee de la Grivette, CETA in Mouy) showed with great accuracy the identical effectiveness of treatments. There was no significant difference as regards yield or specific weights.

Trials have also been carried out on the Caen plain in collaboration with ITCF (Cereal and grass Technical Institute). Results obtained with eyespot are very similar whatever the technique and volume of water used, including the Girojet at 25 l/ha whatever the scale of the attack. Crop penetration was always satisfactory.



Trial:	1405	1406	1412
Crop:	Beauchamps (W Wheat)	Beauchamps (W Wheat)	Beauchamps (W Wheat)
Product:	Captafol/Maneb (Difosan) 2 l/ha	Triadimefon (Bayleton) 2 kg/ha	Prochloraz (Sportak) 1 l/ha
	Fenpropimorph (Corbel) 1 l/ha		Carbendazim (BMC) 0.3kg/ha
	Carbendazim (BMC) 0.4kg/ha		Sulphur 3kg/ha

Girojet 25 l/ha
Conventional 300 l/ha
Conventional 100 l/ha

TABLE D - EAR FUNGICIDE

CETA Mouy and l'Aunette

SUGAR BEET

Post-emergence treatments carried out with CETA in Mouy and Soissons and the Artenay Sugar Co-operative gave results similar to the control references.

Results of ITB (Sugar Beet Technical Institute) in 1983 with the Girojet:

Location: Aulnay aux Planches

20 May - Goltix 2kg/ha pre-emergence treatment

10 June - 2 true-leaf stage of Sugar Beet. Temp 28°C. Girojet 33 l/ha. Speed 6km/h (kilometres per hour).

Betanal 1.5 l/ha
Tramet 1.1 l/ha
Oil 0.5 l/ha

Effectiveness score evaluation on 23 June (for 10 June spraying) was 80%. Weed flora encountered - chenopodium, mercurialis, convolvus and polygonum.

16 June - 4 true-leaf stage of Sugar Beet. Temp 20^{o}C. Girojet 22 l/ha. Speed 6km/h.

Betanal 3 l/ha
Tramet 2 l/ha
Oil 0.5 l/ha

Effectiveness score evaluation on 23 June was 80%.

ITB report that the low volume nozzle proved satisfactory as regards herbicidal effectiveness.

CONCLUSION

Advantages of the Girojet Nozzle

Tests show a good transversal distribution of the spray pattern with penetration due to the vertical positioning. The results from the various authoritive bodies show good effectiveness at the 25 l/ha of carrier, with proprietary products as currently formulated.

Plant toxicity has not appeared to be any different at the higher concentrations than with conventional equipment.

Practical Advantages to the User Are:

Less weight - small tractor requirement
- opportunity of reducing soil compaction
- increase the number of likely working days

More acres per fill - reduces operation downtime
- more acres per day
- improved timeliness

Droplet control - a control of the range of droplet spectra for the target to be sprayed
- reduces the incidence of drift and therefore is more environmentally acceptable.

REFERENCES

ITCF Institut Technique des Cereales et des Fourrages (Cereal Technical Institute)

ITB Institut Technique de Betteraves (Sugar Beet Institute)

CETA Centre d'Etudes Techniques Agricoles (Private Agric Advisors)

GDA Groupement de Developpement Agricole (Official Agric Advisors)

SYSTEM ES, AN ELECTROSTATIC SPRAYING SYSTEM - 1984 U.K. TRIALS

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ABSTRACT

63 trial assemblies of a new charged hydraulic nozzle development, System ES, were distributed amongst a wide variety of trials co-operators worldwide in early 1984. The major purpose of the trials was to establish whether both the efficiency and biological efficacy of conventional hydraulic spraying could be improved by the use of induction charging. Disease pressure was very low, giving unreliable results in all trials, but the wide range of herbicide treatments demonstrated that the technique has some potential for improving biological efficacy, although the improvements were relatively small. Spraying efficiency was greatly improved by the effective use of relatively low volumes of water. The speed of action of some herbicide treatments was increased early after application by charging, although this effect usually gave no lasting improvement to the results. With two exceptions, crop phytotoxicity was not increased by either charging or the use of low volumes of water. A new design of CHN has been introduced for trials in 1985.

INTRODUCTION

With the recent introduction of a number of novel application techniques, it has commonly become acceptable to regard conventional hydraulic spraying as a very inefficient process (Matthews 1981). Yet, despite this stated inefficiency, it remains the most effective system for chemical application in everyday agricultural use (Hislop 1984a). The reasons for this apparent disparity are the subject of much of the present trials work on spraying techniques (Hislop 1984b).

Conventional hydraulic spraying is considered to be inefficient because a) it involves the use of considerable volumes of diluant (typically 100 l/ha and above) and b) it involves the production of a wide range of droplets from a few microns up to 400 microns plus in diameter. The first consideration is a logistical one, in that cartage and turnround time should be minimized in order to maximize the time spent actually spraying (NIAE 1978). The second factor involves considerations both of off-target wastage of chemical and optimization of droplet size for specific uses.

New application techniques, such as controlled droplet application using either rotary atomizers or electrodynamic atomization, have made considerable advances in both of these important areas. Spraying at volumes as low as 1 l/ha is now possible using the ICI 'Electrodyn' with very tight control of droplet size (VMD:NMD ratios closely approaching unity). However, neither of these techniques have matched the efficacy of conventional hydraulic spraying when using equivalent rates of chemical active ingredient (Hislop et al 1984a & b). Also the deposit coefficients of variation at the most commonly used diluant volumes have proven to be very large, often in excess of 100% (Hislop et al 1984b, Robinson et al 1984). Medium volume hydraulic spraying remains the most effective, and reliable, method of chemical application, probably because it involves large numbers of non-uniform droplets.

Using water as the diluant, it is commonly accepted, at least with rotary atomizers, that the most effective droplet size for most applications is c.175 microns (Bailey et al 1982). At a droplet density of 20 drops/cm^2 (sufficient for most residual/translocated herbicides) 4.2 litres of total solution are required of a monodisperse spray to completely cover one hectare of bare earth. Where the target is a crop or weed above ground, however, this requirement increases with the total plant area index:-

TABLE 1

Total plant surface area indices for typical U.K. cereal crops (Bryant 1984)

Crop	Growth stage	LeafAI	StalkAI	Total PlantAI	Stems/m^2
Barley	32	2.69	0.61	3.30	652 ± 56
Barley	37	4.33	1.63	5.96	778 ± 53
Wheat	39	7.72	1.23	8.95	678 ± 13
Wheat	45	6.87	4.23	11.10	584 ± 31

The required volume in this particular set of trials could therefore be 14 - 47 l/ha according to crop and growth stage. With contact fungicides in particular requiring a higher droplet density, in the order of 60 - 70 drops/cm^2 these volume requirements rise to 45 - 150 l/ha. And that presumes total chemical retention by the plant, and complete overall coverage. Selection of water volume according to target growth stage is one important method of increasing spraying efficiency by reducing cartage and turnround time. The effective reduction of carrier volumes can only be achieved when the range of droplet sizes produced by the spraying system is reduced, and overall coverage of the target is maximized. Both of these aims can be achieved by inductively charging the spray (Pay 1984). A prototype charged hydraulic nozzle development System ES, was introduced into large scale trials in 1983, and the results of the 1984 biological trials are described here.

METHODS AND MATERIALS

System ES contains two induction electrodes positioned on either side of a flat fan spray sheet. Excessive return of the oppositely-charged spray cloud is prevented by the use of a specially designed shroud, which, along with the shaped electrode supports, redistributes material by electrostatically forming a stream of droplets. Because of the relative forces acting on them, the smallest droplets within the spray spectrum (those below 70 micron diameter) are most affected by this element of the design, and the proportion of them decreases with charging (Pay 1983 & 1984).

A complete 'ES kit' comprises a cab-mounted 4kV generator/control box running off the tractor 12 volt supply, a live and earth loom for each half of the spray boom, and individual charging 'heads' for each nozzle body. 63 System ES kits were distributed in 1984 amongst chemical and sprayer manufacturers, government and independent research establishments, in the U.K., the U.S.A., continental Europe, Australia and New Zealand. Virtually all were fitted by the manufacturers, Spraycare Application Systems.

Trials were carried out on a large plot and field scale, using a very wide range of commercial agrochemicals. Only 8001, 8002 and 8004 Spraying Systems Inc. nozzle tips were used, and a spray pressure of 285 kPa was recommended, although not always adhered to. The addition of 0.1%v/v Agral was recommended for all solutions to ensure consistent droplet formation from the shroud and electrode supports. All but two of the kits were fitted to boom-mounted sprayers, either hand-held or tractor-mounted. The remaining two were fitted to air-assisted orchard sprayers, a use they were not specifically designed for, but which was investigated on a preliminary basis.

RESULTS

To avoid unfair and inaccurate comparisons between similar products from different manufacturers, results from charging the spray are expressed as percentage deviations from each individual uncharged application. Because of time limitations, only those results fully written up at the time of preperation of this report are included, but from discussion with all of the trials co-operators those included here represent a very fair cross-section of experience.

Cereals

Grassweed herbicides

TABLE 2

difenzoquat (Cyanamid - 5 sites) % weed· control deviation caused by charging

No of sites	% of standard dose	Spray volume (l/ha)	
		75	200
4	100	-3%	+2%
1	75	-2%	+5%

TABLE 3

flamprop-M-isopropyl (Shell) % weed control deviation caused by charging-70DAT

No. of sites	% of standard dose	Spray volume (l/ha)		
		65	124	231
1	100	-2%	0%	-3%

TABLE 4

isoproturon (Ciba-Geigy - 6 sites) % weed control deviation caused by charging

No. of sites	% of standard dose	Spray volume (l/ha)		
		50	100	200
		visual assessment - 21-28DAT		
6	100	+3+	0%	+3%
6	71	+3%	0%	+2%
		head counts - June		
6	100	+2%	+1%	-2%
6	71	+8%	-7%	+4%

Broad-leaved weed herbicides

TABLE 5

Cyanazine/mecoprop (Shell - 2 sites) % weed control deviation caused by charging - 50DAT

No. of sites	% of standard dose	Spray volume (l/ha) 65	124	231
2	100	-1%	-2%	0%
2	50	-6%	-5%	-3%

TABLE 6

bromoxynil/ioxynil/benazoline + mecoprop (3l/ha) (FBC - 4 sites) % weed control deviation caused by charging - 42DAT

Weeds present	Spray volume (l/ha) 54	108	220
Aphanes arvensis	+2%	+1%	-1%
Capsella bursa-pastoria	+2%	0%	+1%
Fumaria officinalis	0%	0%	0%
Lamium amplexicaule	+4%	-2%	-1%
Lamium purpureum	+4%	-7%	-3%
Myosotis arvensis	0%	0%	0%
Stellaria media	+9%	+2%	-1%
Tripleurospermum maritimum spp.	+11%	+2%	-1%
Veronica arvensis	+8%	+4%	+3%
Veronica persica	+1%	+1%	+1%

(Speed of action increased in the early stages when the spray was charged, although the effect did not necessarily show through at final assessment)

TABLE 7

ioxynil/bromoxynil/mecoprop (Ciba-Geigy - 3 sites) % weed control deviation caused by charging - 21DAT

Weeds present	% of standard dose	Spray volume (l/ha) 50	100	200
Papaver rhoeas	100	0%	-1%	0%
Stellaria media	100	+5%	+1%	0%
Veronica persica	100	+1%	+2%	+1%
Papaver rhoeas	67	+2%	+4%	+2%
Stellaria media	67	+7%	-2%	-1%
Veronica persica	67	+3%	-1%	+1%

Some crop phtotoxicity was noticed when spraying this formulation at full dose rate at 50 l/ha, whether the spray was charged or not.

Fungicides

TABLE 8

prochloraz/carbendazim (FBC - 5 sites) % disease control deviation caused by charging

Disease (No. of sites)	Untreated % disease	Spray volume (l/ha) 54	108	220
Mildew - w.wheat(2)	12.5%	+3%	-4%	+3%
Mildew - w.barley(3)	3.8%	+3%	+2%	-3%
Rhynchosporium(2)	1.5%	-13%	+51%	+3%
Eyespot(5)	77.0%	-2%	+4%	-5%

(Stem lesions on 60% of tillers at time of application - foliar diseases very low)

TABLE 9

prochloraz + fenpropimorph (FBC - 6 sites) % disease control deviation caused by charging - 14-21DAT

Disease (No. of sites)	Untreated % disease	Spray volume (l/ha) 54	108	220
Mildew - w.wheat(4)	8%	-8%	-8%	+6%
Mildew - w.barley(2)	48%	+3%	+28%	-8%

TABLE 10

propiconazole (ADAS - High Mowthorpe EHF - 1 site) % disease control deviation caused by charging - 30DAT

Disease (% standard dose)	Untreated % disease	Spray volume (l/ha) 54	108	220
Mildew(100%)	5.3%(leaf 2)	0%	+5%	-7%
Septoria tritici(100%)	8.0%(leaf 2)	+3%	+18%	+5%
Mildew(33%)	5.3%(leaf 2)	+31%	+17%	+10%
Septoria tritici(33%)	8.0%(leaf 2)	+14%	-6%	-4%

TABLE 11

propiconazole (ADAS - Rosemaund EHF - 1 site) Yield (t/ha)

0.5 l/ha Tilt applied on 4 June to Galahad winter wheat at GS 45 with a low level of Septoria (6% of leaf 3) present

Spray volume (l/ha)	54	54	108	108	220	220
Charge (kV)	0	4	0	4	0	4
Yield (t/ha)	11.12	10.92	11.07	11.36	11.06	11.97

Control yielded 10.90 t/ha.

Sugar beet

Grassweed herbicides

TABLE 12

perennial grassweed control trials (BSC - 3 sites) % weed control deviation caused by charging

Trials conducted in volumes of 80 l/ha. Average number of couch shoots in untreated = 248/m^2

Ethyl-2-(4-(6-chloro-2-quinoxalinyloxy)phenoxy) propanoate + oil	+10%
Dow 453	-2%
Sethoxydim + oil	+5%
Fluazifop-P-butyl	-4%

Broad-leaved weed herbicides

TABLE 13

phenmedipham (FBC - 4 sites) % weed control deviation caused by charging - 7DAProgramme

Weeds present	Spray volume (l/ha) 54		108		
	100	57	100	57	%standard dose
Atriplex patula	-5%	0%	0%	-5%	
Chenopodium album	+2%	+2%	0%	0%	
Galium aparine	0%	0%	0%	0%	
Lamium purpureum	+2%	+1%	0%	-1%	
Matricaria spp.	+5%	+2%	+1%	-1%	
Myosotis arvensis	0%	+1%	0%	0%	
Polygonum aviculare	+3%	+2%	0%	+2%	
Polygonum convolvulus	+1%	+2%	0%	+2%	
Polygonum persicaria	+2%	0%	-1%	0%	
Stellaria media	+2%	+1%	0%	+1%	
Thlaspi arvense	+2%	+3%	0%	0%	
Urtica urens	+2%	0%	-2%	+3%	
Veronica hederifolia	+5%	0%	0%	-1%	
Veronica persica	+3%	+3%	-1%	+2%	
Viola spp.	+6%	+5%	0%	+1%	

Although not mentioned here, some local necrosis was noticed with charged low volume applications of metamitron at the cotyledon stage of the beet. This was principally caused by the larger sized droplets formed off the shroud and electrode supports. The trials with metamitron gave extremely variable results, with enormous variations between individual trials, and for that reason are not included in this report.

DISCUSSION

Even assuming perfect recovery of chemical by the crop or weed, 45 l/ha must be accepted as the lowest practical volume for spraying water-based materials. Many of these trials came very close to that limit, and provided a very stiff test for the application system under investigation. Accepting that the lower flow rate hydraulic nozzles produce smaller size droplets we would expect the greatest electrostatic advantages to be shown at the lowest spray volumes.

Overall, that does seem to be the outcome of these particular trials, although the improvements are of a marginal nature. Amongst the grassweed herbicides for cereals, only isoproturon seems to be improved in activity by charging the spray. The HBN/mecoprop cereal herbicides had their activity most enhanced by charging at the lowest volumes. Assessing the absolute control figures in the original trial results shows that low volume application of these types of product is surprisingly effective. With a very low disease year in the U.K. in 1984, any conclusions drawn from the fungicide results would have to be somewhat subjective. All herbicide treatments on sugar beet were very effective, and even the worst results were very respectable when compared with other years.

Accepting the fact that spring/summer 1984 was not a particularly conducive season for application trials in general, and that drift reduction and droplet size control are established benefits of the system, it is generally realised that greater improvements in biological efficacy must be gained from using CHN technology before it becomes a commercial reality.

To this end, Crop Control Products Limited have designed a completely new CHN, and also formulated a very specific, and novel, approach to its use in the field. This new device will be entering a further period of field trials in 1985, building on the solid foundations established in this trials series.

ACKNOWLEDGEMENTS

I am very grateful to all of the companies and organizations who co-operated in the 1984 trials series, each of which made a major contribution to our understanding not only of this particular prototype development, but also of induction charging as a practical method of electrostatic spraying.

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PRELIMINARY EXPERIMENTS ON THE USE OF INDUCTION CHARGED NOZZLES FOR APPLYING A HERBICIDE TO CONTROL BROAD-LEAVED WEEDS IN CEREALS

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Three experiments were carried out in 1984 comparing three sizes of hydraulic fan nozzles with and without electrostatic charging at two rates of herbicide usage. Once experiment was at Bridget's on winter wheat and two at High Mowthorpe, one on winter wheat and one on spring barley.

The nozzles used were Spraying Systems T-jet 8004, 8002 and 8001 delivering 200, 100 and 50 l/ha respectively at 2 bar pressure. In all experiments the herbicide was a mixture of ioxynil, bromoxynil and mecoprop as Swipe 560SCW or Brittox, applied at the recommended rates for the weeds present, or at one third that rate.

The sprayers used at both farms were Allman tractor mounted machines with 12 m booms. The charging equipment was a prototype version of the Spraycare System ES. The experiments were split plot designs with nozzles and rates on main plots and charge on sub plots each 6 m wide.

Experiment 1 Winter wheat at Bridget's EHF

Brittox was applied at 3.5 and 1.2 l/ha on 19 April (crop growth stage 30/31) to a mixed population of *Stellaria media*, *Veronica persica*, *Chenopodium album* and *Papaver rhoeas* all at the 2-4 true leaf stage. Weed control was assessed by measuring weed ground cover in ten 0.1 m^2 quadrats per plot on several occasions.

Effect of charging on weed control and yield

Nozzle/rate	Weed control 26 June (%)		Yield (t/ha)	
	Charge on	Charge off	Charge on	Charge off
			(SED h = 0.321, v = 0.389)	
8004 Full	78.4	78.4	11.08	10.94
8002 "	71.6	70.5	10.97	11.14
8001 "	72.0	69.5	11.02	11.20
8004 Third	63.2	63.2	10.79	11.23
8002 "	58.5	60.0	11.28	11.03
8001 "	50.0	59.4	10.73	11.07
Untreated	63% weed cover		10.06	
Mean	65.6	66.8	10.81	10.99

SE per plot (27 df) =
0.393 t/ha or 3.6% of GM

Charging did not affect the weed control achieved by any of the nozzles at either rate. Marginally better performance was seen from the 8004 nozzles compared with nozzles with smaller orifices. One third rate herbicide gave on average 20% less control. All spray treatments yielded more than the untreated, but did not differ significantly from each other.

Experiment 2 Winter wheat at High Mowthorpe EHF

Swipe 560SCW was applied at 4.5 or 1.5 l/ha on 13 April (crop growth stage 14.23) to a mixture of V. hederifolia, S. media and a few Galium aparine. Weeds ranged in size from small plants to plants 15 cm across. Weed control was assessed by measuring weed ground cover in ten 0.1 m^2 quadrats per plot on 24 May.

Effect of charging on weed control and yield

Nozzle/rate	Weed control (%)		Yield (t/ha)	
	Charge on	Charge off	Charge on	Charge off
			(SED 0.213)	
8004 Full	97.4	95.9	9.03	9.19
8002 "	90.6	92.6	9.29	9.22
8001 "	87.0	85.3	8.86	8.91
8004 Third	58.4	56.4	8.99	8.90
8002 "	68.4	71.2	9.00	9.16
8001 "	69.6	63.7	8.89	8.85
			(SED 0.185)	
Untreated	50.7% ground cover		9.14	
Mean	78.4	79.0	9.03	9.05

SE per plot (27 df) =
0.261 t/ha or 2.9% of GM

Again there was no effect of charging on weed control. The 8004 nozzle was slightly superior to the other nozzles, but only at the full rate of herbicide. One third herbicide on average gave 29% less weed control. The weeds present did not have a competitive effect on the crop and there were no significant differences between yields recorded.

Experiment 3 Spring barley at High Mowthorpe EHF

Swipe 560SCW was applied at 3.0 or 1.0 l/ha on 15 May to spring barley (crop growth stage 13.22) infested with a large number of P. rhoeas and smaller numbers of Aphanes arvensis, Polygonum aviculare, P. convolvulus, Fumaria officinalis, S. media, and G. aparine all at the seedling stage. Many of the first two species survived as stunted plants so weed control was assessed by measuring the dry weight of surviving weed from ten 0.1 m^2 quadrats per plot on 28 June.

Effect of charging on weed control and yield

Nozzle/rate	Weed dry weight (g/m^2)		Yield (t/ha)	
	Charge on	Charge off	Charge on	Charge off
	(SED 6.83)		(SED 0.154)	
8004 Full	1.0	1.0	6.73	6.78
8002 "	3.3	4.0	6.94	6.66
8001 "	5.3	6.9	6.67	6.84
8004 Third	4.3	13.2	6.71	6.61
8002 "	15.5	22.5	6.51	6.40
8001 "	7.7	13.5	6.74	6.70
	(SED 5.92)		(SED 0.133)	
Untreated	28.2		6.66	
	(SED 2.79)		(SED 0.063)	
Mean	6.2	10.2	6.72	6.67
SE per plot (27 df)	8.37 g/m^2 or 75.8% of GM		0.188 t/ha or 2.8% of GM	

At the full rate of herbicide there were no differences in weed dry weight from charging any of the nozzles, but weed control declined slightly with decreasing nozzle size. At the one third rate of herbicide, charging gave consistently better control, though the differences between weed weight did not reach significance ($P<0.05$). There were no effects of nozzle size. Yields did not differ significantly.

Use of the System ES to charge drops had no consistent effects on broad-leaved weed control with any of the nozzles used in these experiments. Since no measurements were made of herbicide deposition, it is not known whether more charged spray than uncharged spray reached the target.