HGCA

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INFLUENCE OF WATER QUALITY ON PESTICIDE EFFICACY AT REDUCED DOSES

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by

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CONTENTS

ABSTRACT

The influence of three sources of mains water on the efficacy of herbicides, aphicides and fungicides was investigated. The water samples were categorised as soft, hard or intermediate, dependent on calcium ion content, and compared to a pure deionised water. The three natural waters had a neutral pH, but differing buffering capacities.

The activity of some of the herbicides was affected by water type, but this was not only related to calcium ion content. Isoproturon (IPU) was less active on chickweed in soft and deionised water, IPU also showed least initial activity on black-grass in deionised water. Metsulfuron methyl was less active on chickweed in the intermediate water. Imazamethabenz showed less response to water type, but there was some indication of improved activity in soft water. HBN gave varied results. It was initially less active against chickweed in the soft water, but this improved later on when it was the hard water which appeared to be least active. Further tests are needed with fenoxaprop-p-ethyl because of black-grass resistance. These results suggest that other ions may also be important factors at affecting herbicide activity, as well as the buffering capacity of the water.

The pyrethroid insecticide lambda-cyhalothrin was effective against aphids in all water samples at the doses tested (down to 25% of full dose). Differences were however observed in the persistence of activity. The hard water reduced the persistence of the aphicide compared to the deionised, soft and intermediate waters.

The fungicide tebuconazole was tested against three wheat powdery mildew strains (*Erysiphe graminis*). Disease control was most consistent with the intermediate and hard water sources, and more variable with the pure and de-ionised waters. This was most pronounced with a mildew strain known to be insensitive to triazole fungicides. This result suggests that water quality may have an influence on fungicide activity, and water sources with high levels of ions may in fact improve disease control.

It can be concluded that the quality of water can influence the efficacy of pesticides, but the differences varied depending upon the pesticide used. The herbicides and fungicide showed a similar pattern where the soft and deionised waters reduced pesticide activity compared to the intermediate and hard waters. Water quality did not affect activity immediately with the insecticide, but persistence of activity was reduced with the hard water. Further research is required to understand the influence of the water quality further, and to exploit these effects to improve pesticide efficacy and reduce pesticide usage.

INTRODUCTION

Reducing pesticide inputs to achieve the most profitable yields and still achieve good control of pests, diseases and weeds, has not taken account of the quality of the water used to deliver the active ingredient to the crop.

Where pesticides are used at manufacturer's recommended doses, the water quality may not be too important considering manufacturers obtain an Approval which demonstrates that a product will provide over 90% control in 90% of circumstances.

Reducing pesticide doses does not necessarily result in a reduced water volume used to deliver sprays, so using a reduced dose also decreases the concentration of other components of a formulated product (e.g. buffers, emulsifiers, wetters, and stickers) in the spray volume as well as the active ingredient.

Nalewaja *et al.* (1990) reported that the activity of the herbicide 2,4-D could be enhanced or antagonised by ions present in the water. Iron and copper salts appeared to enhance its activity, whilst ammonium and potassium salts could antagonise its activity. Nalewaja *et al.* (1989) also commented that the addition of sodium bicarbonate to water could reduce the activity of glyphosate against grass weeds, and this has been re-enforced for a range of cations, for which remediation has been sought (e.g. Roberts, Clark & Mack 1995). Workers at ITCF and INRA, France, have recently confirmed the importance of calcium ions in determining the activity of glyphosate and some other herbicides. However, there has been little published evidence for most pesticide groups, and the amount of public domain based information for the farmer and farm adviser is minimal in this area.

Despite the wide ranges in levels of elements in the water, no account is made of this when pesticide doses are reduced. This contrasts with other industries (e.g. detergent manufacturers) who would suggest different doses of detergent depending upon the 'hardness' of the water. This report describes the results of an initial series of experiments carried out to determine whether water quality influenced the efficacy and persistence of typical and important products from three main groups of pesticides herbicides, insecticides and fungicides. These experiments were designed to indicate whether variation in response to water quality existed in practice, rather than to specifically indicate what qualities of water supplies effected activity. However, analysis of the very different water sources used was undertaken, and allowed some conjecture as to what may be influencing activity. Comparison was made with deionised water, which was assumed would have little or no effect on activity.

During the study, Dr Davies was invited by ITCF Boigneville to attend a meeting titled 'The Efficacy of Herbicides in Hard Water Group' The Group is based on ITCF and INRA, but also includes advisory and trade members. It has the greatest expertise in this area of any working group in Europe. Dr Davies presented some early observations on the results in this study, and a copy of the minutes are attached in Appendix XI

MATERIALS AND METHODS

Water Samples

Water samples were obtained from mains water supplies at three sites in the UK. A control sample of deionised water obtained from Edinburgh. One hundred litres of each water were stored in plastic water carriers, and these samples were used for all the experiments. This ensured that there was no variation in the quality of the water throughout the period of the experiments.

Samples were analysed using an ICAP 61-E made by Thermo Jarrell Ash. The ICP is calibrated using a clean deionised water blank and a standard containing all the elements of interest. The calibration is checked by using a Quality Control (QC) solution containing each element of interest. The sample is analysed, and afterwards the QC is rerun to check that there had been no drift.

For ICP analysis the water samples were filtered and acidified as soon as they arrive at the laboratory. They were filtered through a 0.43 micron filter and 1ml of nitric acid added for every 100ml of sample. The pH is measured using a pH meter with a combined electrode and acidity and alkalinity are measured by potentiometric titration.

Each water was analysed for the presence of dissolved minerals, and for the buffering capacity (see Appendix 1). On the basis of these analyses, the waters were categorised depending upon their buffering capacity. The buffering capacity measures the acidity and alkalinity of waters expressed as mg/l calcium carbonate ($CaCO_3$). The acidity and alkalinity vary separately from the pH, and relate to how easily the addition of an acid or alkali will move the pH of the water. As an extreme example, battery acid and a stream water may both have a pH of 2. One is made up of strong acids, the other weak acids.

Throughout the experiments, the waters are categorised as hard, intermediate, soft or deionised.

Buffering Capacity			Alkalinity (mg Ca_3/ℓ)	Acidity (mg Ca Co_3/ℓ)	Source of water
1.	Hard	- 149 mg/ℓ	224	65	Morley, Norfolk
2.	Intermediate	- 113 mg/ℓ	134	57	Manor Farm, Malton, Yorkshire
3.	Soft	- 12 mg/ℓ	10	15	Boghall Farm, Bush, Penicuik
4.	Deionised	- <0.5 mg/ℓ	2	7	SAC, Edinburgh

The water samples did have some other major variables, notably the high level of barium at Manor Farm (intermediate) and of phosphorus at Morley (hard). The pH was relatively similar in the four water types (7.36-7.78). However, the Hard and Intermediate waters have a much higher acidity and alkalinity than the other two, suggesting the presence of stronger acids and alkalis in these samples.

Herbicides

Weed species

Black-grass (*Alopecurus myosuroides*) and common chickweed (*Stellaria media*) were used as indicator grass and broad-leaved weed species. The seeds, selected from common stocks, were sown into 15 cm diameter pots filled with sterilised soil-based composts; 50 seeds of chickweed, were thinned to 10 plants per pot after emergence and 100 seeds of black-grass thinned to 20 plants per plot. The pots were watered from above as required and maintained in a cool glasshouse regime in 12 hour day/night regime.

Herbicides

The herbicides and doses used are given in Tables 1.1 and 1.2 below. The maximum dose used may not be the maximum utilised in the field, but reflects expected higher levels of activity in greenhouse conditions. Field doses may mask the response curve, so reduced doses are used.

One product tested on the grass weed was Cheetah S (fenoxaprop-p-ethyl). Unfortunately the activity on black-grass was poor and highly variable. We suspect that the sample of seed may have been from a resistant stock, so no valid conclusion can be made. The data for this product has therefore been excluded. However this trial is being repeated with a different black-grass stock, and a short supplement to this report will be prepared on completion of the trial.

Table 1 Herbicide products and doses

1.1 Common chickweed

	Dose g a.i./ha					
	1	2	3	4	5	6
Ally (20% WDG metsulfuron-methyl)	3	1.5	0.75	0.3756	0.188	0
Duplosan (600 g/ℓ mecoprop-p)	60	30	15	7.5	3.75	0
Deloxil (380 g/ℓ bromoxynil/ioxynil)	380	190	95	47.5	23.75	0
Arelon (500 g/ℓ isoproturon)	1250	625	312.5	156.3	78.2	0

1.2 Black-grass

	Dose g a.i./ha					
	1	2	3	4	5	6
Arelon (500 g/ℓ isoproturon)	2500	1250	625	312.5	106.3	0
Dagger (300 g/ℓ imazamethabenz)	600	300	150	75	37.5	0

Ally is manufactured by DuPont (UK) Ltd, Duplosan by BASF (UK) Ltd, Deloxil and Arelon by AgrEvo UK Crop Protection Ltd and Dagger by Cyanamid Agriculture Ltd.

Application

Treatments were applied in 220 ℓ/ha volume at 2.4 bar pressure with an over-passing spray, through medium spray nozzles (T-jet 8003), when the black-grass was at early tillering (approximately 3 tillers) and chickweed at 6-8 leaf growth stages.

Regulation

There were three replicate pots for each treatment, randomised within replicate blocks for each herbicide, re-randomised on a weekly basis.

Assessment

Assessments of foliar damage and growth reduction were undertaken 3, 7 and 14 days after treatment. Fresh and dry matter yields per pot were undertaken 5 weeks after treatment. Fresh weights were determined by cutting plants at the base of the foliage, and whole plot yields weighed. The plant material was then re-weighed after 24 h in a grass dry cabinet. It is these dry weight yields that are reported.

Insecticides

Wheat plants

Wheat seed (cultivar. Riband) which had received no fungicide seed treatment was sown in pots (6 x 5.5 x 5 cm) with John Innes seed and potting compost. Approximately 5 seeds were sown per pot. The pots were kept in a glasshouse where temperatures ranged between 13°C-20°C.

Aphids

Bird cherry aphids (*Rhopalosiphum padi*) were obtained from a culture maintained at CSL, York, and were reared in an insectary on wheat seedlings (cv. Riband) at SAC, Edinburgh to bulk up numbers. Wheat leaves infested with aphids were removed from the culture and placed over the pots containing the wheat plants to be used in the water x aphicide tests. Aphids moved from the infested leaves onto the wheat seedlings (GS12) over following 3 days.

Application of treatments

1) The pyrethroid aphicide lambda-cyhalothrin (Hallmark, Zeneca Crop Protection, Fernhurst, England) was obtained from a local pesticide distributor. Dilutions were made equivalent to the recommended rate of application for aphid control (100 ml/ha in 200 litres water/ha), and diluted to ½, ¼ and 0 rates of insecticide using the four sources of water:

Treatments were applied using a hand-held sprayer which had a medium spray nozzle. All plants were sprayed to run off.

Each treatment consisted of a pot containing approximately 5 aphid infested wheat plants, with 4 replicates of each treatment. Some pots did not exhibit 100% germination so actual numbers of plants per pot varied between 3 and 5.

A further group of plants which were not infested with aphids also received these treatments in order to test the residual effects of the aphicide on aphid survival.

The total number of aphids per treatment on day 0 (day of treatment at wheat GS12), day 1 (24h post treatment), and day 3 were recorded.

2) As a second experiment to determine the residual effect in each water, on day 3, the uninfested plants that had received the aphicide treatments were exposed to aphid infested wheat leaves from the aphid culture. This was carried out in order to determine the longevity of protection from aphids by the different treatments.

This was repeated with a new set of uninfested plants on day 6 and day 9, and the survival of aphids noted 3 days after the aphids were allowed to move from the infested to the uninfested leaves. i.e. Those plants exposed to aphids on day 3 were assessed for aphid survival on day 6, those exposed on day 6 were assessed on day 9 and those exposed on day 9 were assessed on day 12.

Fungicides

Materials

The triazole fungicide tebuconazole was used for all the experiments. Tebuconazole has known activity against some of the powdery mildew isolates used in this study. The methods used follow those currently used to measure fungicide sensitivity as ED_{50} values in resistance screening work.

The winter wheat variety Cerco which carries no known resistance genes for powdery mildew, was used in all experiments to eliminate any varietal resistance effects. Plants were grown in 8 centimetre diameter pots suitable for use on an isolation propagator. Three replicate pots, with three plants in each were used.

The test organism was powdery mildew of wheat *(Erysiphe graminis f sp. tritici)*. Three strains were used as listed in Table 2.

Table 2 Wheat isolates used in experiments

Name	Comment
WC120	sensitive to triazole
WC3	sensitive to triazole
R	insensitive to triazole

Tebuconazole was applied to plants in the different waters at the doses indicated below. The normal dose refers to the formulated product containing 250 g/l tebuconazole (Folicur) with an application rate of 1.0 l/ha.

i) Test fungicide with de-ionised water	0, 1/32, 1/16, 1/8, 1/4 of normal dose
ii) Test fungicide with hard water	0, 1/32, 1/16, 1/8, 1/4 of normal dose
iii) Test fungicide with intermediate water	0, 1/32, 1/16, 1/8, 1/4 of normal dose
iv) Test fungicide with soft water	0, 1/32, 1/16, 1/8, 1/4 of normal dose

Methods

Mildew isolates were bulked twice on whole plants in an isolation propagator to generate sufficient mildew inoculum. This process takes six weeks, after which 20 pots of plants with inoculum from each isolate were obtained.

Test plants were grown in an isolation propagator until plants had reached Zadoks GS13 - 14.
Fungicides were sprayed onto the plants in a perspex spray cabinet using a Humbrol spray gun for 10 seconds.
Mildew spores were subsequently dusted onto plants with a sterile brush, and the plants returned to the isolation propagator and maintained at 18°C with 12 hours daylight.

Assessment

The plant surface area infected with mildew was assessed after 7 and 14 days, and results expressed as EC_{50}. (EC_{50} = effective concentrations resulting in 50% disease suppression).

RESULTS

Herbicides

Chickweed

The average (mean) percent leaf scorch, leaf necrosis and growth reduction 3 days after treatment (DAT) for each treatment is given in Appendix II (a-d), along with scores for foliage yellowing. Appendix III (a-d) gives assessments for 7 DAT and Appendix IV (a-d) for 14 DAT. Mean fresh weights and dry weight assessments are given in Appendix V (a-d). The following sections summarise this data.

(a) Ally (metsulfuron-methyl)

Chickweed showed few early symptoms of Ally activity, with such symptoms typically difficult to assess. However, by 14 DAT the 'intermediate' water treatments were showing markedly reduced activity, as summarised in Table 3.1

Table 3.1 Impact of water type on Ally activity on chickweed, 14 DAT, mean % growth retardation (cf untreated = 0)

		Ally dose code*				
Water type		1	2	3	4	5
1.	Hard	35	30	20	25	25
2.	Intermediate	10	5	5	0	0
3.	Soft	30	35	30	25	20
4.	Deionised	30	35	30	20	20

* See table 1.1 for details of treatments

A harvest there was little difference between the water treatments (Table 3.2).

Table 3.2 Impact of water type on Ally activity on chickweed; dry matter (g)/pot, 4 WAT

		Ally dose code*				
Water type		1	2	3	4	5
1.	Hard	1.76	2.18	2.46	2.51	2.22
2.	Intermediate	1.57	2.25	2.00	2.13	2.67
3.	Soft	1.70	1.98	2.18	1.64	4.45
4.	Deionised	1.73	1.49	2.68	1.78	2.38
	SED±	0.052	0.209	0.185	0.239	0.629

* See table 1.1 for details of treatments

(b) Duplosan (mecoprop-p)

Chickweed rapidly showed symptoms to Duplosan activity with little difference between water types in terms of growth retardation or other symptoms at 3 and 7 DAT. At 14 DAT there was some evidence of reduced activity by dose 2 in hard water (Table 4.1).

Table 4.1 Impact of water type on Duplosan activity on chickweed, 14 DAT, mean % growth retardation (cf untreated = 0)

Water type		Duplosan dose code* 1	2	3	4	5
1.	Hard	20	5	5	5	0
2.	Intermediate	25	25	3	3	0
3.	Soft	25	25	0	3	0
4.	Deionised	20	40	5	0	10

* See table 1.1 for details of treatments

At harvest there was strong indication at low doses (3 and 4) that Duplosan caused most growth reduction when used in hard water, with little difference between other water types or doses (Table 4.2).

Table 4.2 Impact of water type on Duplosan activity on chickweed; dry matter (g)/pot 4 WAT

Water type			Duplosan dose code* 1	2	3	4	5
1.	Hard		1.88	3.08	3.24	3.75	9.96
2.	Intermediate		2.19	2.90	6.58	-	7.12
3.	Soft		2.23	1.85	5.59	5.34	-
4.	Deionised		3.09	1.34	5.20	8.25	5.60
		SED±	0.315	0.509	0.857	1.400	1.805

* See table 1.1 for details of treatments

(c) Deloxil (bromoxynil + ioxynil)

Chickweed showed a rapid response to Deloxil, as would be expected from this treatment, with some indication of greater leaf necrosis with hard and intermediate waters at 3 DAT(Table 5.1), but no dose response in these two water samples. There is a dose response in the soft water, and activity was lower in the soft water and deionised water.

Table 5.1 Impact of water type on Deloxil activity on chickweed, 3 DAT, mean % leaf necrosis (cf untreated = 0)

Water type		Deloxil dose code* 1	2	3	4	5
1.	Hard	20	30	20	25	25
2.	Intermediate	30	30	25	30	20
3.	Soft	10	20	10	0	0
4.	Deionised	0	0	10	10	0

* See table 1.1 for details of treatments

Fourteen DAT there was little difference between water treatments in the degree of overall leaf scorch.

Some differences were apparent, however, in overall plant growth. Results in Table 5.2 show a tendency for reduced activity of Deloxil at dose 3 in the intermediate and hard waters. However, there are no clear differences at other doses.

Table 5.2 Impact of water type on Deloxil activity on chickweed; dry matter (g)/pot, 4 WAT

Water type			Deloxil dose code*				
			1	2	3	4	5
1.	Hard		0.14	0.44	5.12	4.05	4.67
2.	Intermediate		0.43	0.40	4.61	4.05	7.40
3.	Soft		0.47	0.62	1.08	5.10	6.74
4.	Deionised		0.39	-	1.43	3.08	4.67
		SED±	0.091	0.615	1.336	0.503	0.741

* See table 1.1 for details of treatments

(d) Arelon (isoproturon)

Chickweed showed a typically slow response to Arelon treatment, with few symptoms until 7 DAT, and little difference between responses to the different water types.

At Fourteen DAT (Table 6.1), and at harvest (Table 6.2), there was an indication that Arelon was slightly less active in deionised water at doses 2-4 than in the three farm waters; particularly noticeable at dose 4. This may have persisted through to harvest where at dose 4 the highest dry matter was measured following the deionised water treatment., i.e. the lowest activity.

Table 6.1 Impact of water type on Arelon activity on chickweed, 14 DAT, mean % growth reduction (cf untreated = 0)

Water type		Arelon dose code*				
		1	2	3	4	5
1.	Hard	80	85	55	25	5
2.	Intermediate	85	75	55	25	7
3.	Soft	85	70	60	30	5
4.	Deionised	85	50	50	10	5

* See table 1.1 for details of treatments

Table 6.2 Impact of water type on Arelon activity on chickweed; dry matter (g)/pot 4 WAT

Water type		Arelon dose code*				
		1	2	3	4	5
1.	Hard	-	0.12	0.18	0.20	2.47
2.	Intermediate	0.03	0.21	0.11	0.33	2.15
3.	Soft	0.05	0.18	0.12	0.41	2.76
4.	Deionised	0.13	0.14	0.17	1.27	1.65
	SED±	0.048	0.025	0.014	0.296	0.291

* See table 1.1 for details of treatments

Blackgrass

Average (mean) percent leaf scorch, necrosis and growth reduction 3 DAT for each treatment is given in Appendix VI (a-b), along with scores for foliage yellowing. Appendix VII (a-b) gives assessments for 7 DAT and Appendix VIII (a-b) for 14 DAT. Mean fresh weight and dry weight and dry weight assessments are given in Appendix IX (a-b). The following sections summarise this data.

(a) Arelon (isoproturon)

There was no effect seen on black-grass from Arelon treatments 3 DAT, but by 7 DAT there were clear differences between the water samples which were more active than the control deionised water. (Table 7.1) in the level of foliar scorch

Table 7.1 Impact of water type on Arelon activity on black-grass, 7 DAT, mean % leaf scorch (cf untreated = 0)

Water type		Arelon dose code*				
		1	2	3	4	5
1.	Hard	10	15	2	0	0
2.	Intermediate	12	15	3	0	0
3.	Soft	12	10	2	0	0
4.	Deionised	1	0	0	0	0

* See table 1.2 for details of treatments

Table 7.2 Impact of water type on Arelon activity; dry matter (g)/pot, 4 WAT

Water type			Arelon dose code*				
			1	2	3	4	5
1.	Hard		0.85	0.65	1.45	1.33	3.20
2.	Intermediate		0.62	0.87	0.87	1.22	2.78
3.	Soft		0.88	0.61	1.28	1.80	2.75
4.	Deionised		0.58	0.59	0.53	0.67	1.26
		SED±	0.095	0.079	0.255	0.281	0.236

* See table 1.2 for details of treatments

This pattern continued to be evident at 14 DAT. At harvest, however, there was indication that black-grass growth was most reduced in deionised water (notably at doses 3, 4 and 5) than in the natural water types.

(b) Dagger (imazamethabenz)

There were no clear effects of Dagger on black-grass until 7 DAT, when there was a suggestion that Dagger was causing growth reduction, and particularly with the soft water. This was still evident 14 DAT (Table 8.1), particularly for doses 2 and 3.

Table 8.1 Impact of water type on Dagger activity on black-grass, 14 DAT, mean percent growth reduction (cf untreated = 0)

Water type	Dagger dose code*				
	1	2	3	4	5

1.	Hard	40	25	15	5	0
2.	Intermediate	30	20	12	7	7
3.	Soft	40	30	25	5	5
4.	Deionised	30	20	15	5	0

* See table 1.2 for details of treatments

This early observed difference in response to water type was not clearly reflected in the results of the harvest (Table 7.2) assessment.

Table 8.2 Impact of water types on Dagger activity, dry matter (g)/pot, 4 WAT

Water type			Dagger dose code				
			1	2	3	4	5
1.	Hard		1.50	1.95	3.26	2.99	3.93
2.	Intermediate		1.47	2.13	2.98	3.67	3.01
3.	Soft		1.06	1.74	2.45	3.57	3.85
4.	Deionised		1.17	2.21	2.79	3.34	4.67
		SED±	0.134	0.132	0.208	0.185	0.416

Insecticides

Aphid survival

The results for survival of aphids for each of the water x insecticide treatments are shown in Table 9 and Figs. 1 & 2. And in Appendix X.

There were still a few aphids alive 1 day after aphicide treatment (Fig. 1), especially in the hard water 25% dose of aphicide treatment. Mortality reached 100% after 3 days in all aphicide treatments except the soft water 50% aphicide dose treatment where one aphid was alive after 3 days (Appendix X, Fig. 2).

The control (no aphicide) treatments reduced aphid numbers initially resulting in 40-55% mortality depending on the water source (Fig. 1), but after 3 days aphid numbers began to recover (Appendix X) and aphid mortality over 3 days is revised downwards (Fig. 2).

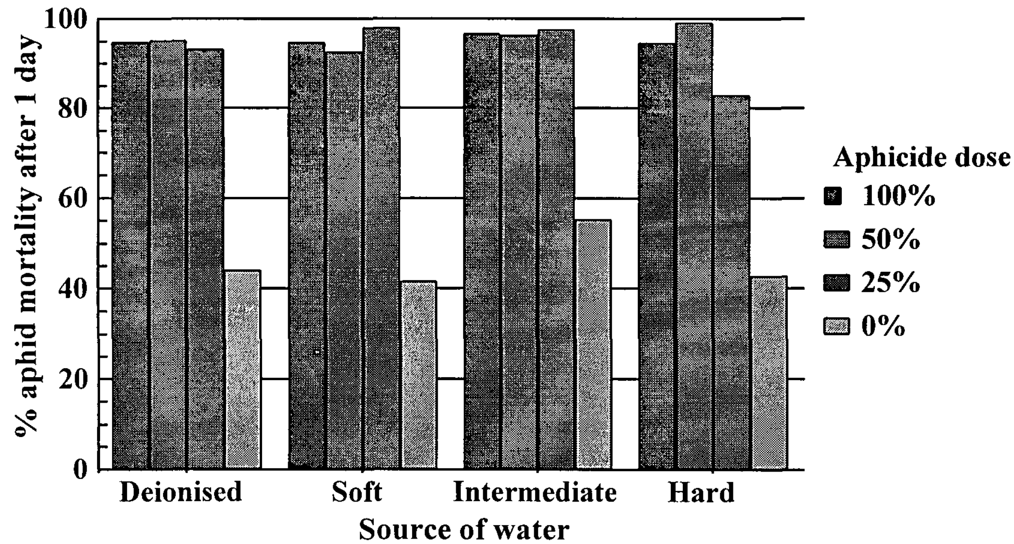

Fig. 1. % aphid mortality 1 day after aphicide treatment.

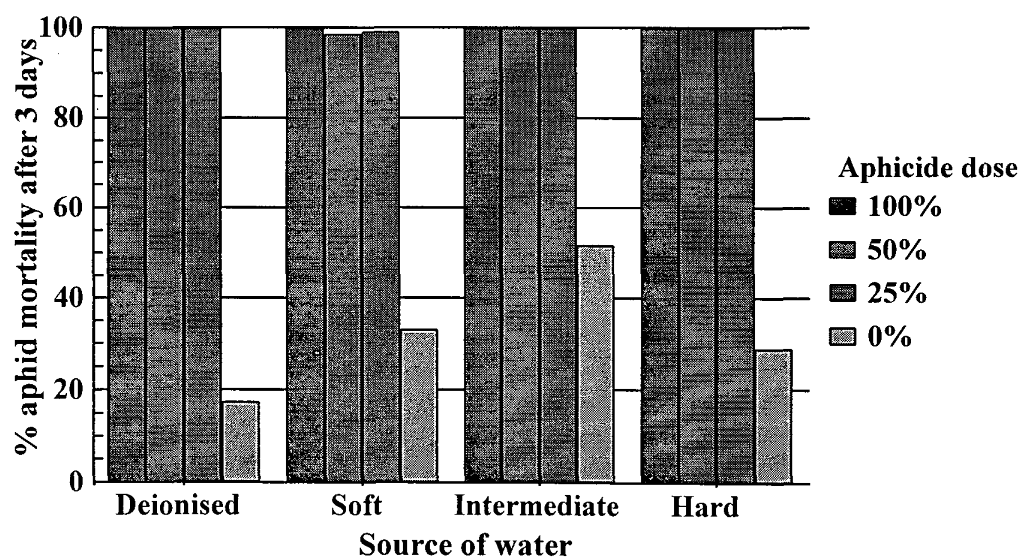

Fig. 2. % aphid mortality 3 days after aphicide treatment.

Table 9. Survival of aphids on wheat plants 3, 6 and 9 days after aphicide x water treatments (aphid survival assessed 3 days after exposure to treated plants)

	Survival of aphids 3 days after exposure to plants with aphicide/water treatments on:								
	Day 3			Day 6			Day 9		
Water source	100%	50%	25%	100%	50%	25%	100%	50%	25%
Deionised	N	Y	Y	N	Y	Y	Y	Y	Y
Soft	N	N	N	Y	Y	Y	Y	Y	Y
Intermediate	N	N	N	N	N	N	Y	Y	Y
Hard	Y	Y	Y	Y	Y	Y	Y	Y	Y

Y indicates aphids alive 3 days after exposure to treated plants,
N indicates no aphid survival

All treatments exhibited some residual aphicidal activity after 3 days except for the hard water treatment where even at full dose (100%) aphicide, aphids survived exposure (Table 9). The deionised, soft and intermediate full dose aphicide treatments retained aphicidal activity after 3 days, but the reduced rate doses (50% and 25%) in deionised water allowed aphids to survive (Table 9).
Aphid exposure to plants 6 days after aphicide treatment led to no survival in the intermediate water treatments at all aphicide doses, but the soft water treatments lost any residual aphicide activity, and only the full aphicide dose of the deionised water retained any aphicidal activity.
After 9 days, all treatments had lost any residual aphicidal activity.

Fungicides

Isolate R was less sensitive to tebuconazole than WC120 and WC3. This resulted in high EC_{50} values in some tests, in particular the deionised water after seven days (Table 10). There is an indication that the intermediate water achieved the best EC_{50} results for isolates WC120 and R. Water quality made no difference to the EC_{50} values seen with isolate WC120.

Table 10 **EC_{50} 7 days post inoculation**

Isolate	EC_{50} Deionised	EC_{50} Soft	EC_{50} Intermediate	EC_{50} Hard
7 days				
WC120	25.16	21.55	20.04	22.48
WC3	22.33	21.02	11.91	24.74
R	225.97	42.01	25.39	39.90

Note a higher EC_{50} indicates a higher dose of fungicide is required to achieve 50% control of mildew

After 14 days for mildew isolate R, there was a high EC_{50} with the deionised water and the soft water, and lower EC_{50} values with the intermediate and hard water (Table 11).

Differences in EC_{50} values between the four water samples were not obvious with mildew isolates WC120 and WC3. The intermediate water did however maintain the lowest EC50 value for all three mildew isolates.

Table 11 **EC_{50} 14 days post inoculation**

Isolate	EC_{50} Deionised	EC_{50} Soft	EC_{50} Intermediate	EC_{50} Hard
14 days				
WC120	28.85	25.79	23.36	30.47
WC3	30.41	31.74	23.55	25.24
R	74.03	74.03	35.66	41.93

As expected, the higher doses of fungicide resulted in lower levels of mildew on the plants with all four water samples (Table 12). The deionised water achieved poorer control of mildew at the low doses of fungicide, suggesting some influence of water quality, albeit small.

The variable results for the resistant mildew in the deionised water meant that differences between EC_{50} values of the average (meaned) data were not significant. However, there was a trend that the intermediate water and hard water achieved lower EC values than the deionised and soft waters. This would tend to indicate that the efficacy of tebuconazole was increased in the intermediate and hard waters.

Table 12 **Dose responses (7 and 14 days meaned)**

Values in table represent % mildew on the plants

	Deionised	Soft	Intermediate	Hard
Fungicide Dose mg/l				
0	15.47	17.74	14.82	11.74
39.06	8.24	5.77	4.64	4.20
78.12	4.26	5.33	2.80	5.09
156.2	4.89	3.43	1.61	2.24
312.5	2.28	2.18	1.70	1.87
SED	3.479	3.256	3.592	2.846
P	0.008	<0.001	0.005	0.013
EC50	67.79	36.02	23.32	30.79
SED	23.993			
P	0.292			

The high variability of the resistant strain resulted in a high standard error when all the results are averaged (Table 13). It was however possible to suggest a trend towards the intermediate water achieving more effective control of mildew compared to the deionised water.

Table 13 **Average EC50 values**

Water	EC50 - 7 days	EC 50 - 14 days
Deionised	91.15	44.43
Soft	28.12	43.85
Intermediate	19.11	27.52
Hard	29.04	32.55
SED	48.153	15.663
P	0.462	0.647

DISCUSSION

Herbicides

General Comment

Although mean dry weight yields per pot are reported, there was considerable variation in seedling growth within and between pots with the population of chickweed used. It is considered that the earlier treatment effects reported are a more consistent guide to the relative activities of the treatments, and the expected field effects. It should be noted that very low rates were tested, and this was considered essential to compare differences between treatments, as herbicide activity tends to be much higher in the greenhouse than in field conditions. However, from experience it can be assumed that differences noted in greenhouse trials may be exaggerated under field conditions, particularly once the impact of crop competition, (missing in these trials), is taken into account.

This is also true for the black-grass treatments. It was also noted that the black-grass population used responded variably and poorly to the Cheetah S treatment, and it is suspected that it may have been in part due to resistance to this herbicide. For that reason these results have been omitted. A small extra trial will be prepared with another population over winter 1998/9 and reported as supplement to this report.

Chickweed

The trials show a considerable variation in response to the herbicides depending on the water used, and would indicate that at least initial differences in activity would occur in the field dependent on water type in the case of Ally, IPU, Duplosan and Deloxil.

There was a clear reduction in early Ally activity in the intermediate water, and of Duplosan activity in the hard water. But in the case of Duplosan, activity in terms of chickweed dry matter was eventually greatest in the hard water. Deloxil activity was initially greatest in the hard and intermediate waters, but chickweed appeared to recover more by harvest from these treatments than from Deloxil treatment with the soft water. Arelon did not show a marked difference in response to local water type but was less active initially when used in deionised water, and this was possibly reflected in the final chickweed harvest. It is of interest that early effects did not necessarily correspond to final chickweed results. Whether such differences would be seen in field and crop competition conditions is not clear, and warrants assessment. We have found no information in the literature on factors that may influence the differences seen in the these herbicide responses, and the differences in activity over time in different water types.

Workers at ITCF have noted that another sulfonyl-urea, Lexus (flupyrsulfuron) , activity is reduced in acid water due to reduced solubility. They have also found metsulfuron is less stable in acidic conditions, increasing activity. The waters tested varied little in pH, but the intermediate water had high acid and alkali buffering capacity compared with the soft water, and a reduced ratio of alkali: acid buffering compared with the hard water. Whether this or another factor related to differences in ionic components caused the differences in Ally response between the hard and soft and intermediate waters is not known, and requires further study.

The reduced activity of Arelon in deionised water may suggest that an ion or ions unknown are required to be present to maintain activity on chickweed. It is also possible that buffering ratios effects activity, and this warrants further analysis. It is, however, surprising that an active ingredient considered to be primarily taken up through the root system is affected by water quality. It could be suggested that the reduced early foliar effects due to use of deionised water may be due to unknown factors of water quality, but ultimately the root uptake largely, although perhaps not completely, overcame such differences. Whether understanding the component that improved early foliar activity may lead to improved foliar uptake, and whether such uptake would prove a valuable asset in the use of isoproturon is open to hypothesis.

Black-grass

Arelon showed a similar and possibly greater effect on black-grass than with chickweed in terms of an early reduced effect on black-grass in deionised water compared with local water supplies, than with chickweed. The response of black-grass to Dagger x water type was much smaller, with some indication of higher activity in the soft water type.

As indicated for the activity on chickweed above, the early pattern of isoproturon response is surprising, and may warrant further testing, although again final weed control is not affected, and may indeed have been improved in the case of blackgrass. Once again greater understanding of the factors involved may allow more efficient and effective use of isoproturon.

Insecticides

All sources of water were effective at killing aphids present on treated wheat leaves at aphicide doses from 100% to 25%. The only differences appeared to be in the time to achieve 100% mortality, as the Hard 25% aphicide treatment only gave just over 80% mortality after 24h, but this rose to 100% after 3 days. The only aphicide treatment not to achieve 100% control after 3 days was the soft 50% treatment, but this was down to a single aphid that managed to survive the aphicide treatment.
Differences between treatments became apparent when the residual activity of the aphicide treatments was studied.
Three days after aphicide application, only the soft and intermediate treatments retained aphicidal activity at all doses, whilst the hard water showed no activity. The deionised water treatment was only effective at full (100%) aphicide dose. After 6 days only the intermediate aphicide treatments and the 100% deionised water treatment retained any residual aphicidal activity. After 9 days all treatments had lost aphicidal activity.

The reduced doses applied all gave very high levels of aphid mortality one day after treatment under the glasshouse conditions used. Differences between doses were not therefore apparent, except an indication that hard water only achieved 80% mortality with the 25% dose. Any repetition of this work would utilise lower doses in order to show more subtle variations of initial mortality.

Differences were more obvious in the persistence of the insecticide. The differences were again most obvious with the hard water which achieved poorer persistence compared to the other water samples. These results suggest that water quality does have an effect on persistence of activity. This result may have implications not only for the efficacy of treatments to crops, but also to the persistence of pesticides in water courses.

Fungicides

There was a trend for deionised water to reduce the efficacy of tebuconazole in controlling powdery mildew, and for activity to increase in the hard and intermediate waters.

The variation in EC_{50} values was higher with the deionised water than with the intermediate and hard waters. The intermediate water achieved more consistent control of mildew than the others, and this was most marked when comparing the intermediate with the deionised water, and when looking at the results for the resistant mildew (strain R)
This is something worth investigating further, because there has been no other information to suggest that the sensitivity of powdery mildew to fungicides is influenced by the quality of the water.

Colleagues at ITCF have indicated that vine growers in the South of France started using deionised water for mildew sprays, in order to increase activity. However, it is believed that the use of deionised water reduced the activity of the fungicides, which would concur with these results. However, this has not been tested experimentally.

VISIT TO ITCF BY DR DAVIES

As part of the background to this work, Dr Davies visited ITCF Boigneville, France, to join a regular meeting on The Activity of Herbicides and Hard Water to look at their work and facilities, as outlined in the Introduction. The report of the papers at the meeting is appended, including comments from this work. A short English report on the main points is included in Appendix X1. It is clear that the French workers have concentrated on the impact of hard waters, and in particular the impact of calcium ions, but expressed great interest in the results of the HGCA funded work, and wish to join us in future studies. They have shown clear differences in response in -fops and -dims, glyphosate, glufosinate and flupyrsulfuron, amongst herbicides, and some differences with other pesticides (reported elsewhere). They have extensive facilities for controlled environment and field testing at Boigneville.

CONCLUSIONS

There is evidence from these studies that the activity of pesticides varies in response to different water types, and that this may be related to the presence or absence of specific ions, or the relative buffering capacity of the water. Tebuconazole, the fungicide used, was least effective in deionised water and most efficient in hard and intermediate waters. A similar pattern emerged for the activity of the herbicides used, with the deionised water tending to reduce efficacy, and for efficacy to be increased in the hard or intermediate waters. Duplosan activity against chickweed was greatest in the hard water. Deloxil also showed increased activity in the hard and intermediate waters. Arelon was least active in deionised water, against both chickweed and blackgrass.

The results from the aphicide suggested that the doses used were all effective at killing aphids immediately after treatment, but the persistence of the aphicide was least when applied with the hard water. Any repetition of this work would utilise lower doses in order to show more subtle variations in knock down activity.

The conventional view is that calcium ions, and perhaps other factors associated with hard water are implicated in reducing pesticide activity, Indeed there are products designed to reduce the availability of certain cations (notably calcium). These trials however suggest that for some pesticides the absence of key ions, and/or other factors associated with buffering capacity, may be at least as important. The importance of the absence of key ions, or aspects related to buffering capacity, in activity is suggested by the reduced response of tebuconazole in deionised water, and at least the reduced initial activity of other products, noticeably isoproturon.

Also of interest is the variation in response in isoproturon to water type is unexpected, given that this product is largely active through root uptake. A degree of foliar uptake has always been suspected, and perhaps it is this component which has been reduced by the use of deionised water, and may be encouraged by the use of specific ions.

It is known that sulfonyl urea herbicides respond differently to pH of spray water and soil. However, the results with metsulfuron suggest that other factors may be as important. As an example, as pH between the three mains water types tested was very similar, the fact that the early activity of metsulfuron was clearly reduced in the intermediate water type (intermediate calcium content), would suggest another unknown factor related to this water type was important.

The variation in persistence of activity in the insecticide and fungicide treatments in response to water treatment has not in our knowledge, been recorded before. Similarly, the evidence that the sensitivity of a pathogen, in this case powdery mildew strains, to a fungicide may vary according to water type is, to our knowledge, new.

It should be noted that these trials were all undertaken under glasshouse or other controlled conditions. We can only surmise what may have been the responses under field conditions, and this needs testing. Nevertheless, these results indicate that variation in pesticide activity may in part be due to variation in water type. This could explain variations in regional responses that we are aware of at the extension level. This is of particular importance in designing appropriate pesticide and dose strategies, and in the production of decision support systems.

It is of interest that French colleagues, can clearly link their controlled work results with field experience, and that local advisory services utilise their results at the practical farm level, after local field confirmation testing. Indeed, in some cases, the preferred herbicide by the trade and advisers in certain areas depends on the results of trials testing herbicide activity with variations in water quality.

It is evident from this study that the responses of pesticides to water types is more complex than even the French workers have determined. We suggest that further research should be undertaken to examine which are the key factors in water quality that most consistently effect pesticide activity, and how any reduction in activity may be controlled. This may be possible by using various buffering agents and ionic exchange materials, or in the case of some treatments, adding key ions to the spray tank. At the practical farm level, the local water supply can be readily and cheaply analysed, and is usually a one-off analysis. One can envisage the local spray operator both selecting the best pesticide, and the dose based on the water type, and possibly add specific compounds to the spray tank to promote optimum activity for his water type. For the adviser, selection of both pesticide and dose for optimum activity with regard to the local water supply would also be possible. The availability of such information would also have uses in the development of decision support systems for precision in farm spray operations.

We recommend that future research should include key pesticide groups, and the testing of the impact of water qualities should be undertaken using an additive approach. That is the key factors (such as calcium, phosphates, iron etc.) are added to a deionised, neutral water supply in a systematic manner. Ideally we would hope that key factors can be associated with pesticide groups, or even with the sensitivity of specific pathogens. Initially only those factors showing major impact on activity will warrant further field confirmation, but apart from calcium and pH, there appears to be little understanding of what are the key factors.

This study concentrated on measuring the differences in pesticide efficacy using different water samples. The varying concentration of ions in water may have other more physical effects (i.e. influence droplet size, drift etc.) which are not covered in this report. Having established that water quality does influence pesticide efficacy, future work would concentrate on understanding why there are differences, and how these can be used to optimise pesticide applications to field crops.

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APPENDICES

APPENDIX I Analysis of waters used in experiments (30 April 1998)

Element	Units	SAC Edinburgh	Boghall Midlothian	Manor Farm Yorks	Morley Norfolk
		Deionised	Soft	Intermediate	Hard
pH		7.51	7.78	7.36	7.72
Alkalinity	mg $CaCO_3$/l	2	10	134	224
Acidity	mg $CaCO_3$/l	7	15	57	65
Sulphur	mg/l	7.51	5.51	21.8	10.3
Magnesium	mg/l	<0.10	2.51	9.24	4.13
Sodium	mg/l	<0.350	<0.350	6.23	6.98
Potassium	mg/l	<2.20	<2.20	<2.20	<2.20
Calcium	mg/l	<0.050	12.4	113	149
Aluminium	µg/l	<80.0	<80.0	<80.0	<80.0
Iron	µg/l	<230	<230	<230	<230
Manganese	µg/l	<4.0	<4.00	<4.0	<4.00
Copper	µg/l	<11.0	21.7	<11.0	<11.0
Zinc	µg/l	<9.0	<9.0	<9.0	<9.0
Phosphorus	µg/l	<220	<220	<220	287
Cadmium	µg/l	<14.0	<14.0	<14.0	<14.0
Chromium	µg/l	<13.0	<13.0	<13.0	<13.0
Nickel	µg/l	<30.0	<30.0	<30.0	<30.0
Lead	µg/l	<110	<110	<110	<110
Boron	µg/l	<45.0	<45.0	<45.0	<45.0
Barium	µg/l	<4.00	10.9	88.4	30.9

APPENDIX II **Herbicide activity 3 DAT: chickweed**

(a) HGCA Water Quality Herbicides: Ally

18 May 1998, 3 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	10	0
5	Deionised	0	9	3	0
4	Deionised	0	9	0	0
3	Deionised	0	9	0	0
2	Deionised	0	9	0	0
1	Deionised	0	9	0	0
6	Soft	0	9	10	0
5	Soft	0	9	0	0
4	Soft	0	9	0	0
3	Soft	0	9	0	0
2	Soft	0	9	0	0
1	Soft	0	9	0	0
6	Intermediate	0	9	0	0
5	Intermediate	0	9	0	0
4	Intermediate	0	9	0	0
3	Intermediate	0	9	0	0
2	Intermediate	0	9	0	0
1	Intermediate	0	9	0	0
6	Hard	0	9	10	0
5	Hard	0	9	3	0
4	Hard	0	9	0	0
3	Hard	0	9	0	0
2	Hard	0	9	0	0
1	Hard	0	9	0	0

APPENDIX II **Herbicide activity 3 DAT: chickweed**

(b) HGCA Water Quality Herbicides: Duplosan

18 May 1998, 3 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	9	0	0
4	Deionised	0	8	0	2
3	Deionised	0	8	0	10
2	Deionised	0	7	0	25
1	Deionised	0	7	0	40
6	Soft	0	9	0	0
5	Soft	0	9	0	0
4	Soft	0	8	0	3
3	Soft	0	8	0	10
2	Soft	0	7	0	25
1	Soft	0	7	0	40
6	Intermediate	0	9	0	0
5	Intermediate	0	9	0	0
4	Intermediate	0	9	0	1
3	Intermediate	0	8	0	10
2	Intermediate	0	7	0	20
1	Intermediate	0	7	0	40
6	Hard	0	9	0	0
5	Hard	0	9	0	0
4	Hard	0	8	0	10
3	Hard	0	8	0	7
2	Hard	0	7	0	20
1	Hard	0	7	0	40

APPENDIX II **Herbicide activity 3 DAT: chickweed**

(c) HGCA Water Quality Herbicides: Deloxil

18 May 1998, 3 DAT

Treatment					
Dose code	Water type	% Leaf scorch	Foliage yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	7	8	0	1
4	Deionised	10	8	10	5
3	Deionised	15	8	10	10
2	Deionised	15	8	0	25
1	Deionised	35	7	0	25
6	Soft	0	9	0	0
5	Soft	7	8	0	3
4	Soft	10	8	0	5
3	Soft	20	8	10	15
2	Soft	25	7	20	20
1	Soft	35	7	0	20
6	Intermediate	0	9	20	0
5	Intermediate	7	8	20	1
4	Intermediate	10	8	30	5
3	Intermediate	20	8	25	15
2	Intermediate	15	8	30	15
1	Intermediate	35	7	30	30
6	Hard	0	9	0	0
5	Hard	7	8	25	1
4	Hard	12	8	25	5
3	Hard	15	7	20	10
2	Hard	20	7	30	20
1	Hard	40	7	20	40

APPENDIX II **Herbicide activity 3 DAT: chickweed**

(d) HGCA Water Quality Herbicides: Deloxil

18 May 1998, 3 DAT

Treatment					
Dose code	Water type	% Leaf scorch	Foliage yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	9	0	0
4	Deionised	0	9	0	0
3	Deionised	0	9	0	0
2	Deionised	0	9	0	0
1	Deionised	2	9	0	2
6	Soft	0	9	0	0
5	Soft	0	9	0	0
4	Soft	0	9	0	0
3	Soft	0	9	0	0
2	Soft	1	9	0	0
1	Soft	3	9	0	2
6	Intermediate	0	9	0	0
5	Intermediate	0	9	0	0
4	Intermediate	0	9	0	0
3	Intermediate	0	9	0	0
2	Intermediate	0	9	0	0
1	Intermediate	3	9	0	2
6	Hard	0	9	0	0
5	Hard	0	9	0	0
4	Hard	0	9	0	0
3	Hard	0	9	0	0
2	Hard	1	9	0	1
1	Hard	1	9	0	1

APPENDIX III **Herbicide activity 7 DAT: chickweed**

(a) HGCA Water Quality Herbicides: Ally

22 May 1998, 7 DAT

Treatment					
Dose code	Water type	% Leaf scorch	Foliage yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	10	0
5	Deionised	0	7	5	15
4	Deionised	0	7	10	15
3	Deionised	0	6	12	15
2	Deionised	0	5	20	20
1	Deionised	0	5	30	15
6	Soft	0	9	3	0
5	Soft	0	8	5	10
4	Soft	0	7	12	20
3	Soft	0	7	15	20
2	Soft	0	6	15	25
1	Soft	0	9	25	20
6	Intermediate	0	8	3	0
5	Intermediate	1	8	5	5
4	Intermediate	0	7	10	0
3	Intermediate	1	7	15	0
2	Intermediate	0	6	15	5
1	Intermediate	0	6	25	10
6	Hard	0	9	3	0
5	Hard	0	8	5	15
4	Hard	0	7	10	15
3	Hard	0	7	15	15
2	Hard	0	7	20	15
1	Hard	0	6	25	20

APPENDIX III **Herbicide activity 7 DAT: chickweed**

(b) HGCA Water Quality Herbicides: Duplosan

22 May 1998, 7 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	8	0	0
4	Deionised	0	9	0	0
3	Deionised	0	8	0	5
2	Deionised	0	7	0	20
1	Deionised	0	7	0	15
6	Soft	0	9	0	0
5	Soft	0	8	0	5
4	Soft	0	8	0	5
3	Soft	0	9	0	0
2	Soft	0	6	0	20
1	Soft	0	7	0	15
6	Intermediate	0	9	0	0
5	Intermediate	0	9	0	3
4	Intermediate	0	7	0	7
3	Intermediate	0	8	0	3
2	Intermediate	0	7	0	15
1	Intermediate	0	6	0	15
6	Hard	0	9	0	0
5	Hard	0	9	0	0
4	Hard	0	8	0	5
3	Hard	0	7	0	7
2	Hard	0	7	0	3
1	Hard	0	6	0	15

APPENDIX III **Herbicide activity 7 DAT: chickweed**

(c) HGCA Water Quality Herbicides: Deloxil
22 May 1998, 7 DAT

Treatment					
Dose code	Water type	% Leaf scorch	Foliage yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	10	8	5	3
4	Deionised	25	7	15	25
3	Deionised	35	6	20	25
2	Deionised	40	6	0	30
1	Deionised	70	5	0	70
6	Soft	0	9	0	0
5	Soft	10	7	15	10
4	Soft	15	7	20	25
3	Soft	40	6	25	50
2	Soft	50	6	0	60
1	Soft	80	5	0	80
6	Intermediate	0	9	15	0
5	Intermediate	10	7	20	10
4	Intermediate	20	7	25	25
3	Intermediate	20	6	35	45
2	Intermediate	40	6	40	55
1	Intermediate	70	5	0	75
6	Hard	0	9	0	0
5	Hard	7	7	15	15
4	Hard	25	7	20	20
3	Hard	35	6	25	45
2	Hard	50	5	0	60
1	Hard	70	5	0	75

APPENDIX III **Herbicide activity 7 DAT: chickweed**

(d) HGCA Water Quality Herbicides: Arelon

22 May 1998, 7 DAT

Treatment					
Dose code	Water type	% Leaf scorch	Foliage yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	3	8	0	0
4	Deionised	10	7	0	3
3	Deionised	10	7	0	20
2	Deionised	20	6	0	20
1	Deionised	45	5	0	30
6	Soft	0	9	0	0
5	Soft	3	8	0	3
4	Soft	12	6	0	15
3	Soft	7	7	0	20
2	Soft	25	6	0	30
1	Soft	50	5	0	40
6	Intermediate	0	9	0	0
5	Intermediate	5	8	0	2
4	Intermediate	12	7	0	3
3	Intermediate	20	6	0	20
2	Intermediate	30	6	0	25
1	Intermediate	50	5	0	30
6	Hard	0	9	0	0
5	Hard	5	8	0	0
4	Hard	7	7	0	5
3	Hard	15	7	0	15
2	Hard	35	6	0	30
1	Hard	45	5	0	20

APPENDIX IV **Herbicide activity 14 DAT: chickweed**

(a) HGCA Water Quality Herbicides: Ally

29 May 1998, 14 DAT

Treatment					
Dose code	Water type	% Leaf scorch	Foliage yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	5	0
5	Deionised	0	6	12	20
4	Deionised	0	6	25	20
3	Deionised	0	5	60	30
2	Deionised	0	4	70	35
1	Deionised	0	4	75	30
6	Soft	0	9	0	1
5	Soft	0	7	5	20
4	Soft	0	6	25	25
3	Soft	0	5	60	30
2	Soft	0	4	70	35
1	Soft	0	4	75	30
6	Intermediate*	3	9	15	0
5	Intermediate	0	8	20	0
4	Intermediate	0	7	25	0
3	Intermediate	0	6	50	5
2	Intermediate	0	6	60	5
1	Intermediate	0	5	75	10
6	Hard	0	9	3	0
5	Hard	2	7	10	25
4	Hard	0	6	20	25
3	Hard	0	5	50	20
2	Hard	0	5	60	30
1	Hard	0	5	75	35

*Control small plants

APPENDIX IV **Herbicide activity 14 DAT: chickweed**

(b) HGCA Water Quality Herbicides: Duplosan

29 May 1998, 14 DAT

Treatment					
Dose code	Water type	% Leaf scorch	Foliage yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	7	0	10
4	Deionised	0	9	0	0
3	Deionised	0	8	0	5
2	Deionised	0	7	0	40
1	Deionised	0	6	0	20
6	Soft	0	9	0	0
5	Soft	0	7	0	0
4	Soft	0	7	0	3
3	Soft	0	9	0	0
2	Soft	0	7	0	25
1	Soft	0	6	0	25
6	Intermediate	0	9	0	0
5	Intermediate	0	8	0	0
4	Intermediate	0	7	0	3
3	Intermediate	0	9	0	3
2	Intermediate	0	7	0	25
1	Intermediate	0	7	0	25
6	Hard	0	9	0	0
5	Hard	0	9	0	0
4	Hard	0	7	0	5
3	Hard	0	8	0	5
2	Hard	0	7	0	5
1	Hard	0	6	0	20

APPENDIX IV **Herbicide activity 14 DAT: chickweed**

(c) HGCA Water Quality Herbicides: Deloxil

29 May 1998, 14 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	2	9	3	0
5	Deionised	10	8	7	2
4	Deionised	20	7	10	25
3	Deionised	35	6	5	30
2	Deionised	25	7	0	35
1	Deionised	90	2	0	90
6	Soft	1	9	0	0
5	Soft	10	7	0	7
4	Soft	15	6	15	20
3	Soft	45	5	20	50
2	Soft	75	3	0	70
1	Soft	85	2	0	90
6	Intermediate	1	9	5	0
5	Intermediate	10	7	10	10
4	Intermediate	25	5	25	25
3	Intermediate	20	5	50	40
2	Intermediate	60	4	30	65
1	Intermediate	85	3	0	90
6	Hard	0	9	0	0
5	Hard	10	7	10	15
4	Hard	30	5	15	20
3	Hard	40	6	45	40
2	Hard	60	4	0	65
1	Hard	90	3	0	85

APPENDIX IV **Herbicide activity 14 DAT: chickweed**

(d) HGCA Water Quality Herbicides: Arelon

29 May 1998, 14 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	25	7	0	5
4	Deionised	50	6	0	10
3	Deionised	75	4	0	50
2	Deionised	70	4	0	50
1	Deionised	90	2	0	85
6	Soft	0	9	0	0
5	Soft	25	7	0	5
4	Soft	65	5	0	30
3	Soft	75	4	0	70
2	Soft	80	3	0	60
1	Soft	90	2	0	85
6	Intermediate	5	9	0	0
5	Intermediate	25	7	0	7
4	Intermediate	60	5	0	25
3	Intermediate	75	4	0	55
2	Intermediate	80	2	0	75
1	Intermediate	90	2	0	85
6	Hard	0	9	0	0
5	Hard	25	7	0	5
4	Hard	55	4	0	25
3	Hard	75	4	0	55
2	Hard	80	2	0	85
1	Hard	90	2	0	80

APPENDIX V **Herbicide activity 4 WAT: chickweed**

(a) HGCA Water Quality Herbicide: Ally

16 June 1998

Treatment Dose code	Water type	Fresh wt (g) Rep 1	Fresh wt (g) Rep 2	Fresh wt (g) Rep 3	Dry wt (g) Rep 1	Dry wt (g) Rep 2	Dry wt (g) Rep 3	DM % Rep 1	DM % Rep 2	DM % Rep 3
6	Deionised	71.01	63.85	53.83	10.51	9.27	8.19	14.80	14.51	15.21
5	Deionised	10.66	4.74	5.69	3.12	2.10	1.93	29.26	44.30	33.91
4	Deionised	7.70	6.51	2.68	2.02	2.18	1.14	26.23	33.48	42.53
3	Deionised	9.13	6.53	4.90	2.87	3.12	2.05	31.43	47.77	41.83
2	Deionised	2.24	3.44	2.70	1.30	1.74	1.43	58.03	50.58	52.96
1	Deionised	2.60	3.00	2.12	1.67	2.06	1.47	64.23	68.66	69.33
6	Soft	67.26	79.08	65.05	10.02	12.08	9.43	14.89	15.27	14.49
5	Soft	18.37	12.12	49.69	3.64	3.42	6.29	19.81	28.21	12.65
4	Soft	9.64	3.81	3.62	2.71	0.86	1.36	28.11	22.57	37.57
3	Soft	2.91	5.87	3.71	1.48	3.28	1.78	50.85	55.87	47.97
2	Soft	6.27	2.01	1.40	3.41	1.54	0.98	54.38	76.61	70.00
1	Soft	3.02	2.22	2.47	1.92	1.63	1.56	63.57	73.42	63.15
6	Intermediate	9.82	39.43	8.08	1.86	5.02	1.47	18.94	12.73	18.19
5	Intermediate	7.10	6.97	9.87	2.62	2.31	3.08	36.90	33.14	31.20
4	Intermediate	3.93	7.37	6.50	1.29	2.75	2.35	32.82	37.31	36.15
3	Intermediate	4.88	3.62	8.25	2.13	1.16	2.70	63.64	32.04	32.72
2	Intermediate	3.10	4.50	4.13	2.01	2.44	2.29	64.83	54.22	55.44
1	Intermediate	2.20	1.44	4.00	1.40	0.92	2.38	63.63	63.88	59.50
6	Hard	60.11	97.10	81.11	8.71	13.40	11.49	14.49	13.80	14.16
5	Hard	6.37	10.38	7.08	1.76	2.67	2.25	27.62	25.72	31.77
4	Hard	5.15	9.47	5.89	2.06	3.61	1.87	40.00	38.12	31.74
3	Hard	7.18	7.49	5.81	2.73	2.61	2.04	38.02	34.84	35.11
2	Hard	3.76	3.54	5.79	1.92	1.99	2.64	51.06	56.21	45.59
1	Hard	5.12	2.48	1.37	2.83	1.45	1.00	55.27	58.46	72.99

APPENDIX V **Herbicide activity 4 WAT: chickweed**

(b) HGCA Water Quality Herbicide: Duplosan

16 June 1998

Treatment Dose code	Water type	Fresh wt (g) Rep 1	Fresh wt (g) Rep 2	Fresh wt (g) Rep 3	Dry wt (g) Rep 1	Dry wt (g) Rep 2	Dry wt (g) Rep 3	DM % Rep 1	DM % Rep 2	DM % Rep 3
6	Deionised	45.61	34.86	46.36	5.80	4.88	6.20	12.71	13.99	13.37
5	Deionised	29.96	13.11	13.24	3.81	1.62	1.82	14.13	12.35	13.74
4	Deionised	70.35	34.26	69.98	9.19	6.92	8.65	13.06	20.19	12.36
3	Deionised	42.51	41.99	29.06	6.66	5.24	3.69	15.66	12.47	12.69
2	Deionised	14.07	7.89	8.50	1.88	0.97	1.18	13.36	12.29	13.88
1	Deionised	25.23	16.25	15.43	3.47	3.17	2.62	13.75	19.50	16.97
6	Soft	61.03	47.76	45.89	7.18	6.33	6.58	11.76	13.25	14.33
4	Soft	35.06	23.03	59.37	5.10	3.20	7.72	14.54	13.89	13.00
3	Soft	51.98	44.80	37.14	6.35	5.44	4.97	12.21	12.14	13.38
2	Soft	17.91	14.10	8.83	2.62	1.82	1.11	14.62	12.90	12.57
1	Soft	15.93	16.63	11.18	2.49	2.64	1.56	15.63	15.87	13.95
6	Intermediate	71.85	52.44	73.11	9.92	6.97	9.95	13.80	13.29	13.60
5	Intermediate	58.80	66.86	29.31	8.01	8.94	4.41	13.62	13.37	15.04
3	Intermediate	49.82	71.86	42.10	6.78	8.28	4.67	13.60	11.52	11.09
2	Intermediate	29.61	16.27	13.88	4.46	2.34	1.90	15.06	14.38	13.68
1	Intermediate	11.64	22.44	9.05	1.89	3.55	1.14	16.23	15.81	12.59
6	Hard	22.62	22.22	21.79	2.73	3.28	3.15	12.06	14.76	14.45
5	Hard	79.37	68.10	65.10	10.76	9.57	9.54	13.55	14.05	14.65
4	Hard	23.30	17.77	29.44	3.70	3.03	4.51	15.87	17.05	15.31
3	Hard	18.01	7.30	52.85	2.40	0.89	6.43	13.32	12.19	12.16
2	Hard	18.74	28.94	20.78	2.64	3.93	2.66	14.08	13.57	12.80
1	Hard	14.97	9.26	12.33	2.36	1.31	1.98	15.76	14.14	16.05

APPENDIX V **Herbicide activity 4 WAT: chickweed**

(c) HGCA Water Quality Herbicide: Deloxil

16 June 1998

Treatment Dose code	Water type	Fresh wt (g) Rep 1	Fresh wt (g) Rep 2	Fresh wt (g) Rep 3	Dry wt (g) Rep 1	Dry wt (g) Rep 2	Dry wt (g) Rep 3	DM % Rep 1	DM % Rep 2	DM % Rep 3
6	Deionised	29.84	11.97	20.01	3.27	1.63	2.47	10.95	13.61	12.34
5	Deionised	40.87	38.77	32.20	5.24	5.04	3.72	12.82	12.99	11.55
4	Deionised	21.95	26.77	24.74	2.57	3.78	2.90	11.70	14.12	11.72
3	Deionised	13.41	8.41	10.92	1.73	1.22	1.34	12.90	14.50	12.27
1	Deionised	0.35	3.52	1.90	0.26	0.59	0.31	74.28	16.76	16.31
6	Soft	40.05	75.02	75.85	6.34	11.43	10.94	15.83	15.23	14.42
5	Soft	47.24	54.46	51.75	6.17	6.94	7.13	13.06	12.74	13.77
4	Soft	61.60	37.61	35.53	5.80	5.05	4.44	13.94	13.42	12.49
3	Soft	4.10	17.46	7.50	0.41	2.08	0.74	10.00	11.91	9.86
2	Soft	2.81	2.37	11.73	0.38	0.26	1.21	13.52	10.97	10.31
1	Soft	0.58	7.31	2.01	0.32	0.79	0.31	55.17	10.80	15.42
6	Intermediate	55.80	75.43	80.33	8.33	10.28	10.74	14.92	13.62	13.36
5	Intermediate	44.73	55.83	52.71	6.55	8.41	7.24	14.64	15.06	13.73
4	Intermediate	16.87	20.39	53.44	2.19	2.63	7.33	12.98	12.98	13.71
3	Intermediate	39.40	44.24	39.78	5.15	4.59	4.09	13.07	10.37	10.28
2	Intermediate	5.74	2.86	0.24	0.70	0.45	0.06	12.19	15.73	25.00
1	Intermediate	0.99	1.79	0.81	0.49	0.57	0.23	49.49	31.84	28.39
6	Hard	59.62	89.74	84.92	8.32	12.62	10.56	13.95	14.06	12.43
5	Hard	47.46	43.47	46.69	7.60	6.67	6.49	16.01	15.34	13.90
4	Hard	15.15	34.17	38.80	2.13	4.63	5.38	14.05	12.54	14.04
3	Hard	41.76	43.94	35.28	5.29	5.55	4.51	12.66	12.63	12.78
2	Hard	3.65	1.87	2.30	0.42	0.43	0.46	11.50	22.99	20.00
1	Hard	0.71	1.07	0.23	0.15	0.19	0.09	21.12	17.75	39.13

APPENDIX V **Herbicide activity 4 WAT: chickweed**

(d) HGCA Water Quality Herbicide: Arelon

16 June 1998

Treat ment Dose code	Water type	Fresh wt (g) Rep 1	Fresh wt (g) Rep 2	Fresh wt (g) Rep 3	Dry wt (g) Rep 1	Dry wt (g) Rep 2	Dry wt (g) Rep 3	DM % Rep 1	DM % Rep 2	DM % Rep 3
6	Deionised	19.92	7.29	29.98	2.86	2.46	4.34	14.35	14.22	14.47
5	Deionised	7.95	14.23	18.93	1.03	1.69	2.24	12.95	11.87	11.83
4	Deionised	1.29	21.64	0.38	0.93	2.66	0.22	72.09	12.29	57.89
3	Deionised	0.18	0.17	0.61	0.06	0.09	0.36	33.33	52.94	59.01
2	Deionised	0.38	0.26	0.26	0.23	0.06	0.14	60.52	23.07	53.84
1	Deionised	0.39	0.17	0.21	0.21	0.14	0.05	53.84	82.35	23.80
6	Soft	45.39	36.15	36.40	6.08	5.18	2.97	13.39	14.32	13.15
5	Soft	17.64	20.00	29.22	2.26	2.37	3.66	12.81	11.85	12.52
4	Soft	0.58	0.57	0.67	0.42	0.29	0.54	72.41	50.87	80.59
3	Soft	0.18	0.58	0.14	0.09	0.25	0.02	50.00	43.10	14.28
2	Soft	0.20	0.22	0.35	0.08	0.14	0.31	40.00	63.63	88.57
1	Soft	0.27	0	0.26	0.06	0.00	0.09	22.22	0.00	34.61
6	Intermediate	28.39	44.76	34.70	3.37	6.50	5.05	11.87	14.52	14.55
5	Intermediate	25.62	14.89	12.00	3.30	1.77	1.38	12.88	11.88	11.50
4	Intermediate	0.37	0.39	0.80	0.30	0.32	0.39	81.98	82.05	48.75
3	Intermediate	0.10	0.51	0.07	0.03	0.30	0.01	30.00	58.82	14.28
2	Intermediate	0.21	0.31	0.50	0.07	0.22	0.34	33.33	70.96	68.00
1	Intermediate	0.15	0.04	0.14	0.07	0.00	0.02	46.66	0.00	14.28
6	Hard	26.57	30.60	17.86	3.35	4.30	2.32	12.60	14.05	13.00
5	Hard	39.00	10.84	10.33	4.99	1.23	1.20	12.79	11.34	11.61
4	Hard	0.39	0.32	0.09	0.27	0.27	0.07	69.23	84.37	77.77
3	Hard	0.48	0.27	0.32	0.21	0.14	0.19	43.75	51.85	59.37
2	Hard	0.45	0.00	0.32	0.24	0.00	0.12	53.33	0.00	37.50
1	Hard	0.75	0.31	0.44	0.47	0.12	0.23	62.66	38.70	52.27

APPENDIX VI **Herbicide activity 3 DAT: black-grass**

(a) HGCA Water Quality Herbicides: Arelon

4 May 1998, 3 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	9	0	0
4	Deionised	0	9	0	0
3	Deionised	0	9	0	0
2	Deionised	0	9	0	0
1	Deionised	0	9	0	0
6	Soft	0	9	0	0
5	Soft	0	9	0	0
4	Soft	0	9	0	0
3	Soft	0	9	0	0
2	Soft	0	9	0	0
1	Soft	0	9	0	0
6	Intermediate	0	9	0	0
5	Intermediate	0	9	0	0
4	Intermediate	0	9	0	0
3	Intermediate	0	9	0	0
2	Intermediate	0	9	0	0
1	Intermediate	0	9	0	0
6	Hard	0	9	0	0
5	Hard	0	9	0	0
4	Hard	0	9	0	0
3	Hard	0	9	0	0
2	Hard	0	9	0	0
1	Hard	0	9	0	0

APPENDIX VI **Herbicide activity 3 DAT: black-grass**

(b) HGCA Water Quality Herbicides: Dagger

4 May 1998, 3 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	9	0	0
4	Deionised	0	9	0	0
3	Deionised	0	9	0	0
2	Deionised	0	9	0	0
1	Deionised	0	8	0	0
6	Soft	0	9	0	0
5	Soft	0	9	0	0
4	Soft	0	9	0	0
3	Soft	0	9	0	0
2	Soft	0	9	0	0
1	Soft	0	8	0	0
6	Intermediate	0	9	0	0
5	Intermediate	0	9	0	0
4	Intermediate	0	9	0	0
3	Intermediate	0	9	0	0
2	Intermediate	0	9	0	0
1	Intermediate	0	8	0	0
6	Hard	0	9	0	0
5	Hard	0	9	0	0
4	Hard	0	9	0	0
3	Hard	0	8	0	0
2	Hard	0	8	0	0
1	Hard	0	7	3	0

APPENDIX VII **Herbicide activity 7 DAT: black-grass**

(a) HGCA Water Quality Herbicides: Arelon

8 May 1998, 7 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	9	0	0
4	Deionised	0	9	0	0
3	Deionised	0	8	0	0
2	Deionised	0	8	0	3
1	Deionised	0	8	0	10
6	Soft	0	9	0	0
5	Soft	0	9	0	0
4	Soft	0	9	0	0
3	Soft	2	8	0	0
2	Soft	10	7	0	15
1	Soft	12	7	0	15
6	Intermediate	0	9	0	0
5	Intermediate	0	9	0	0
4	Intermediate	1	9	0	0
3	Intermediate	3	8	0	3
2	Intermediate	15	8	0	15
1	Intermediate	12	7	0	15
6	Hard	0	9	0	0
5	Hard	0	9	0	0
4	Hard	0	8	0	0
3	Hard	2	7	0	3
2	Hard	15	7	0	15
1	Hard	10	7	0	15

APPENDIX VII **Herbicide activity 3 DAT: black-grass**

(b) HGCA Water Quality Herbicides: Dagger

4 May 1998, 3 DAT

Treatment					
Dose code	Water type	% Leaf scorch	Foliage yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	8	0	0
4	Deionised	0	8	0	3
3	Deionised	0	7	0	10
2	Deionised	0	6	0	10
1	Deionised	0	5	0	15
6	Soft	0	9	0	0
5	Soft	0	8	0	3
4	Soft	0	8	0	3
3	Soft	0	6	0	20
2	Soft	0	5	0	15
1	Soft	0	4	0	30
6	Intermediate	0	9	0	0
5	Intermediate	0	8	0	2
4	Intermediate	0	8	0	3
3	Intermediate	0	7	0	5
2	Intermediate	0	6	0	10
1	Intermediate	0	5	0	15
6	Hard	0	9	0	0
5	Hard	0	8	0	0
4	Hard	0	7	0	3
3	Hard	0	7	0	7
2	Hard	0	6	0	10
1	Hard	0	5	0	20

APPENDIX VIII **Herbicide activity 14 DAT: black-grass**

(a) HGCA Water Quality Herbicides: Arelon

15 May 1998, 14 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	8	0	2
4	Deionised	10	7	0	25
3	Deionised	15	6	0	30
2	Deionised	25	5	0	50
1	Deionised	30	4	0	60
6	Soft	0	9	0	0
5	Soft	1	9	0	0
4	Soft	15	7	0	10
3	Soft	40	4	0	40
2	Soft	80	3	0	65
1	Soft	75	3	0	70
6	Intermediate	0	9	0	0
5	Intermediate	0	9	0	3
4	Intermediate	30	7	0	15
3	Intermediate	40	4	0	45
2	Intermediate	80	3	0	65
1	Intermediate	80	3	0	70
6	Hard	0	9	0	0
5	Hard	0	9	0	2
4	Hard	30	7	0	12
3	Hard	35	6	0	35
2	Hard	70	5	0	55
1	Hard	65	4	0	60

APPENDIX VIII **Herbicide activity 14 DAT: black-grass**

(b) HGCA Water Quality Herbicides: Dagger

15 May 1998, 14 DAT

Treatment			Foliage		
Dose code	Water type	% Leaf scorch	yellowing 0-9	% necrosis	% growth retard.
6	Deionised	0	9	0	0
5	Deionised	0	8	0	0
4	Deionised	0	7	3	5
3	Deionised	3	6	3	15
2	Deionised	3	6	10	20
1	Deionised	10	4	15	30
6	Soft	0	9	0	0
5	Soft	0	8	0	5
4	Soft	3	8	2	5
3	Soft	3	6	7	25
2	Soft	5	4	10	30
1	Soft	10	3	15	40
6	Intermediate	0	9	0	0
5	Intermediate	0	8	2	7
4	Intermediate	1	7	3	7
3	Intermediate	1	6	3	12
2	Intermediate	3	6	3	20
1	Intermediate	7	5	10	30
6	Hard	0	9	0	0
5	Hard	0	8	0	0
4	Hard	2	7	2	5
3	Hard	5	7	3	15
2	Hard	7	6	7	25
1	Hard	10	5	15	40

APPENDIX IX **Herbicide activity 4 WAT: Black-grass**

(a) HGCA Water Quality Herbicide: Arelon

01 June 1998

Treat ment		Fresh	Fresh	Fresh	Dry	Dry	Dry			
Dose code	Water type	wt (g)	wt (g)	wt (g)	wt (g)	wt (g)	wt (g)	DM %	DM %	DM %
		Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
6	Deionised	27.75	42.33	37.25	3.73	5.24	4.70	13.44	12.37	12.61
5	Deionised	25.05	20.30	22.63	2.77	2.12	2.37	11.05	10.44	10.47
4	Deionised	3.28	2.22	4.04	0.66	0.63	0.73	20.12	28.37	18.06
3	Deionised	1.73	2.42	6.59	0.39	0.41	0.78	22.54	16.94	11.83
2	Deionised	2.32	1.30	1.29	0.82	0.46	0.48	35.34	35.38	37.20
1	Deionised	1.33	1.80	1.41	0.49	0.60	0.65	36.84	33.33	46.09
6	Soft	27.59	27.50	32.96	5.07	4.73	5.56	18.37	17.20	16.86
5	Soft	20.81	18.64	21.26	2.88	2.60	2.87	13.83	13.94	13.49
4	Soft	8.76	12.05	13.36	1.47	1.86	2.06	16.78	15.43	15.41
3	Soft	3.06	6.74	1.86	1.38	1.54	0.92	45.09	22.84	49.46
2	Soft	2.04	1.13	0.36	0.99	0.65	0.20	48.52	57.52	55.55
1	Soft	1.46	2.01	1.44	0.72	1.21	0.72	48.97	60.19	50.00
6	Intermediate	28.15	41.91	31.15	4.76	7.13	5.44	16.90	17.01	17.46
5	Intermediate	27.07	13.55	19.59	3.73	1.71	2.82	13.77	12.61	14.39
4	Intermediate	5.66	2.98	3.51	1.07	1.06	1.53	18.90	35.57	43.58
3	Intermediate	3.44	1.44	1.58	1.30	0.66	0.66	37.79	45.83	41.77
2	Intermediate	1.66	1.71	1.56	0.77	0.96	0.89	46.38	56.14	57.05
1	Intermediate	1.28	2.17	0.73	0.58	0.95	0.33	45.31	43.77	45.20
6	Hard	31.07	24.59	30.52	5.09	3.73	5.28	16.38	15.16	17.30
5	Hard	19.04	15.68	19.23	2.38	1.98	2.41	12.50	12.62	12.53
4	Hard	2.70	12.87	1.87	1.29	1.89	0.75	47.77	14.68	40.10
3	Hard	3.56	7.75	2.41	1.43	1.68	1.25	40.16	21.67	51.86
2	Hard	1.78	1.50	1.08	0.78	0.56	0.61	43.82	37.33	56.48
1	Hard	2.20	0.85	2.00	1.19	0.47	0.88	54.09	55.29	44.00

APPENDIX IX **Herbicide activity 4 WAT: Black-grass**

(b) HGCA Water Quality Herbicide: Dagger

01 June 1998

Treatment Dose code	Water type	Fresh wt (g) Rep 1	Fresh wt (g) Rep 2	Fresh wt (g) Rep 3	Dry wt (g) Rep 1	Dry wt (g) Rep 2	Dry wt (g) Rep 3	DM % Rep 1	DM % Rep 2	DM % Rep 3
6	Deionised	18.90	23.91	26.00	4.53	4.52	4.62	23.96	18.90	17.76
5	Deionised	25.98	25.72	21.50	4.75	4.64	3.27	18.28	18.04	15.20
4	Deionised	26.39	26.48	20.27	3.76	3.40	2.85	14.24	12.83	14.06
3	Deionised	20.55	21.49	17.26	3.14	2.90	2.33	15.27	13.49	13.49
2	Deionised	13.38	16.67	17.41	1.94	2.42	2.27	14.49	14.51	13.03
1	Deionised	6.38	5.61	8.61	1.11	1.01	1.40	17.39	18.00	16.26
6	Soft	23.59	26.98	29.86	4.20	4.81	5.57	17.80	17.82	18.65
5	Soft	24.75	31.97	18.50	3.85	4.85	2.85	15.55	15.17	15.40
4	Soft	27.47	27.62	24.62	3.86	3.75	3.09	14.05	13.57	12.55
3	Soft	14.72	14.56	23.37	2.25	1.92	3.19	15.28	13.18	13.64
2	Soft	9.06	8.09	13.96	1.70	1.23	2.28	18.76	15.20	16.33
1	Soft	6.49	4.58	6.45	1.08	1.01	1.10	16.64	22.05	17.05
6	Intermediate	21.05	25.28	24.44	4.37	4.43	4.42	20.76	17.52	18.08
5	Intermediate	20.96	16.79	23.23	3.10	2.31	3.63	14.79	13.75	15.62
4	Intermediate	31.05	36.51	27.17	3.48	4.15	3.37	11.20	11.36	12.40
3	Intermediate	18.92	23.16	23.86	3.03	2.54	3.38	16.01	10.96	14.16
2	Intermediate	15.12	12.62	19.65	2.19	1.42	2.79	14.48	11.25	14.19
1	Intermediate	11.01	13.96	5.71	1.56	1.90	0.97	14.16	13.61	16.98
6	Hard	25.91	24.61	24.04	4.84	4.12	4.18	18.68	16.74	17.38
5	Hard	22.97	20.21	28.54	3.73	3.39	4.67	16.23	16.77	16.36
4	Hard	24.61	23.09	28.60	2.51	2.65	3.80	10.19	11.47	13.28
3	Hard	22.23	26.66	25.10	3.37	3.19	3.22	15.15	11.96	12.82
2	Hard	16.42	11.43	16.67	2.11	1.70	2.03	12.85	14.87	12.17
1	Hard	9.63	7.96	10.71	1.36	1.37	1.78	14.12	17.21	16.16

APPENDIX X a) Aphid numbers and level of control of different water/aphicide treatments pre- and post-treatment

Total No. of aphids/treatment and level of control after 3 days

		Number of aphids			
Water source	**Aphicide Conc (%)**	**Day 0**	**Day 1**	**Day 3**	**% Control after 3 days**
Deionised	100	136	7	0	100
	50	150	7	0	100
	25	150	10	0	100
	0	120	67	99	18
Soft	100	96	5	0	100
	50	139	10	2	99
	25	107	2	1	99
	0	127	74	85	33
Intermediate	100	126	4	0	100
	50	56	2	0	100
	25	83	2	0	100
	0	112	50	54	52
Hard	100	94	5	0	100
	50	128	1	0	100
	25	53	9	0	100
	0	91	52	65	29

APPENDIX X b) Mean aphid numbers in different water/aphicide treatments pre- and post-treatment

		Mean No. aphids/plant		
Water source	Aphicide Conc %	Day 0	Day 1	Day 3
Deionised	100	7.2	0.4	0
	50	8.3	0.4	0
	25	7.5	0.5	0
	0	7.1	3.9	5.8
Soft	100	5.6	0.3	0
	50	7.3	0.5	0.1
	25	5.9	0.1	0.1
	0	6.4	3.7	4.2
Intermediate	100	6.0	0.2	0
	50	3.1	0.1	0
	25	4.2	0.1	0
	0	5.1	2.3	2.5
Hard	100	5.9	0.3	0
	50	5.8	0.1	0
	25	2.9	0.5	0
	0	5.7	3.2	4.1
SED +/-		3.40	1.30	1.80

APPENDIX X1 Meeting on the effect of water qualities on pesticide activity

ITCF Boigneville, France
28 November 1998

This meeting was attended on behalf of SAC by K Davies, Crops Division, in order to develop a working relationship upon which further work can be founded, and research funding sought. This follows, and is part of, an initial HGCA-funded project examining whether differences in activity in different waters do exist amongst major cereal pesticide products. Results from these trials were presented to the members of the French Eaux Dures Group.

A full set of minutes will become available from the French rapporteur; I list below some key points:

Glyphosate

Roundup; Increasing Calcium consistently reduces activity. The addition of an adjuvant improves activity , but not to the full extent.

Touchdown (Ouragan): Sulfosate also shows a similar effect, and ammonium sulphate assists activity, with an adjuvant, such as Ethokem T25. This clearly helps penetration of the foliage. The higher the temperature the more active the combination.

Sting: Calcium has little effect on Sting, but acidity reduces activity.

Dims

There is some indication of an increase in activity with higher Calcium in Centurion, cycloxydim (Status) and sethoxydim (Fervinal), but not significant in Status.

Ogive (cycloxydim) - differences in degree of activity between deionised and hard water at 34°f and 62°f; after 47d there was no differences in activity at full dose, but at lower doses the deionised water treatment was less active.

Glufosinate

Basta (Challenge): differences seem between sites in response to Calcium could this be due to other ions present?

Liberty: probably bigger differences than with Basta, but not really significant.

Sulfonyl-ureas

Lexus: acidity reduces solubility, which reduces activity. Ammonium sulphate improves activity slightly on black-grass, as well as increasing Calcium content at Boigneville - but not at Dijon. Rimsulfuron and tribenuron are less stable in acidic conditions as is metsulfuron.

I described SAC results with metsulfuron, mecoprop-p, HBN, IPU and imazamethaben.

Fungicides

They found no significant differences in Opus activity with hardness, with only a slight trend to greater activity in soft water.

I pointed out SAC results with tebuconazole, and the local pathologist also pointed out that it was thought that vineyard owners have also seen a loss in activity in deionised water and soft water with fungicides.

BASF strobilurin not showing an effect to Calcium.

Insecticides

I outlined results with Lambda-cyclohethrin at SAC.

General

The group are keen to work with SAC in this area, and suggest our presence at future meetings. I pointed out this is dependent on funding, and they are happy to be involved in any such project with the HGCA.