Project Report No. 421

October 2007

Price: £3.50

Developing an effective strategy for the sustainable control of Italian rye-grass (*Lolium multiflorum*)

by

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This is the final report of a 54 month project, which started in August 2002. The project was funded by a contract of £74,046 from HGCA (Project no. 2735).

Contents

ABSTRACT

The aim of the project was to identify specific aspects of crop and herbicide management that would optimise control of Italian rye-grass (*Lolium multiflorum*) in wheat with a range of herbicides. This would reduce reliance on one specific mode of action, leading to the more sustainable herbicide use.

The information generated has enabled a more effective strategy for the sustainable control of Italian rye-grass to be developed which should help to avoid resistance to the mode of action of iodosulfuron + mesosulfuron (Atlantis), the dominant herbicide used for rye-grass control.

This project has contributed to a sustainable strategy for controlling Italian rye-grass in the following ways:

- Alternatives to Atlantis and its mode of action, such as chlorotoluron, Axial (pinoxaden), Crystal (flufenacet + pendimethalin), Ingot (diflufenican + flurtamone + isoproturon), Grasp (tralkoxydim) when applied at the optimum growth stage of the weed can provide effective control of rye-grass where herbicide resistance does not significantly reduce efficacy. However, these may not provide adequate control of moderate to high populations of black-grass (*Alopecurus mysosuroides*) that may also be present.
- There is little innate dormancy in Italian rye-grass at the time when winter cereals are sown and there is likely to be significant emergence soon after the seedbed has become thoroughly moist. The lack of dormancy results in reduced numbers of Italian rye-grass emerging in later-drilled winter wheat.
- Contrary to farming folklore, there appears to be no secondary peak of emergence in the spring of Italian rye-grass in winter wheat. Similar numbers appear to emerge after mid-November in crops drilled from mid-September to mid-October. The lack of a ‘spring flush’, together with a similar emergence from mid-November, may explain why applications of herbicides in the autumn provide effective season-long control. There can be an advantage from applying post-emergence herbicides at the one-leaf stage of the weed rather than the three-leaf stage. The extent of the advantage will depend on the herbicide in question and the resistance status of the weed.
- Typically, the moisture content of the surface layers of the soil will not significantly affect the level of control of non herbicide-resistant populations. When the soil is very dry the control achieved by Atlantis may be reduced.

SUMMARY

INTRODUCTION

At the time of the inception of this project, Italian rye-grass (*Lolium multiflorum*) infestations in winter wheat were increasing and some farmers were experiencing difficulty in control. This was exacerbated in many cases by herbicide resistance to some of the most effective selective herbicides in cereals, including target site resistance to the aryloxyphenoxy-propionates (‘fops’) and cyclohexanediones (‘dims’). The introduction of the very effective herbicide Atlantis WG (iodosulfuron + mesosulfuron) in 2003 has tended to mask the scale of the problem but there are concerns that resistance to its mode of action may eventually lead to poor control.

The aim of the project was to identify specific aspects of crop and herbicide management that would lead to the control of Italian rye-grass in wheat with a range of herbicides in order to reduce reliance on one specific mode of action.

TIME OF EMERGENCE OF THE WEED

Recording time of emergence for three years revealed a similar pattern. There was significant emergence within two to three weeks of the surface layers of the soil becoming thoroughly moist. Despite differences in drilling dates, the emergence patterns from mid-November onwards were similar. There was not a secondary peak of emergence in the spring in the years of the experiments (Figure 1). These observations explain why autumn-applied herbicides provide effective control.

INFLUENCE OF WEED SIZE ON HERBICIDE ACTIVITY

Post-emergence herbicides varied in relative efficacy when applied to weeds at the one-leaf stage rather than the three-leaf stage. The efficacy of Ingot (diflufenican + flurtamone + isoproturon) and Grasp (tralkoxydim) was particularly sensitive to weed size and provided better control when applied to weeds at the one-leaf stage. The efficacy of chlorotoluron and Atlantis were less influenced by weed size (Figure 2). In the final year of the project a field experiment was held on a site with high levels of enhanced metabolism resistance as well as target site resistance to the ‘fops’ and ‘dims’. This level of resistance exaggerated the impact of size of weed on herbicide activity and also indicated that Atlantis could be more effective when applied at the one-leaf stage of the weed rather than at the three-leaf stage in this situation (Figure 3).

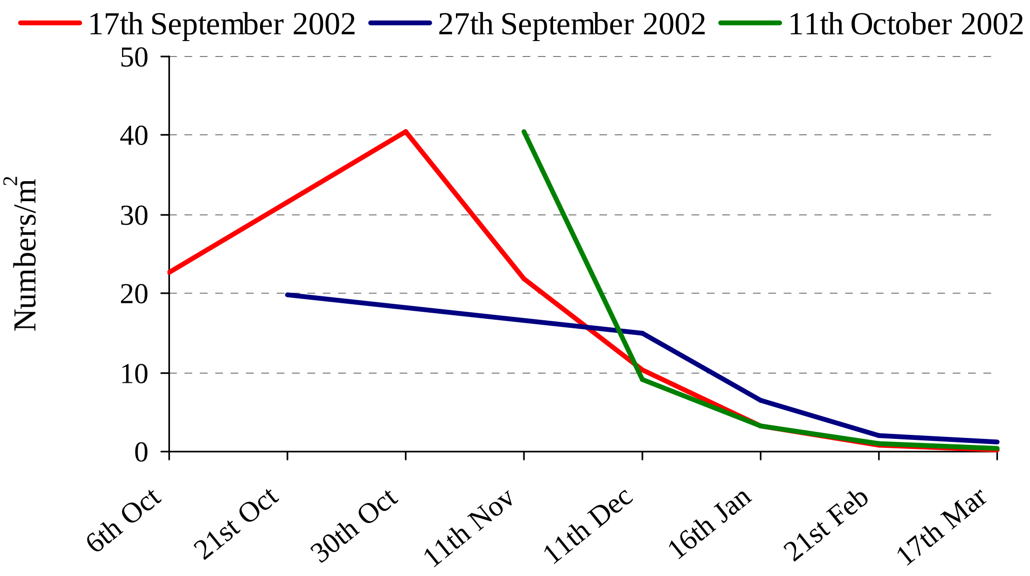

Figure 1. *Emerged rye-grass plants/m^2 since sowing (17th September, 27thSeptember, 11th October) or the previous recording date in plots sown on three different dates in a commercial field in Norfolk, autumn 2002 (soil conditions were dry until 12th October).*

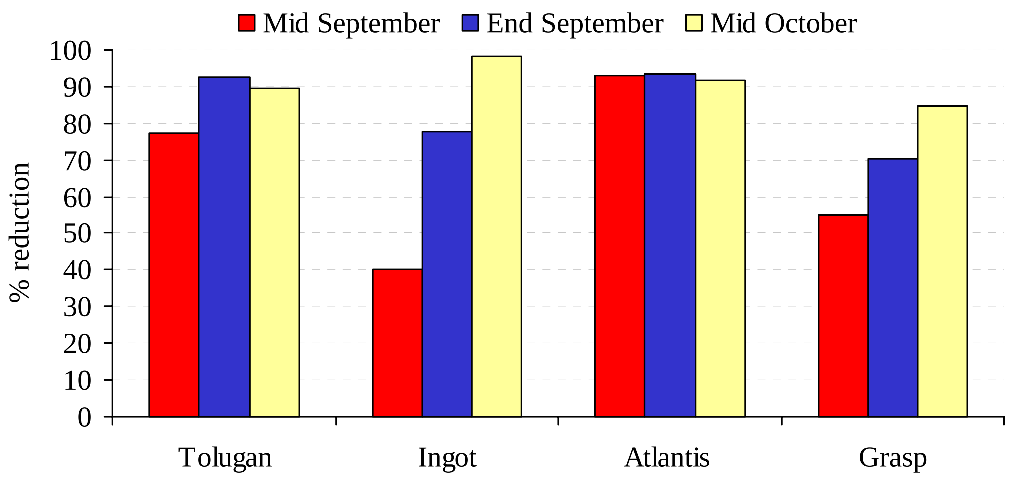

Figure 2. *Percentage reduction in Italian rye-grass heads in June 2003 when a range of herbicides were applied on 31st October 2002 to an experiment in a commercial field in Norfolk drilled in mid September (size of weed at the time of spraying was 2-3 leaves), end September (size of weeds 1-2 leaves) or mid October (size of weeds 1 leaf).*

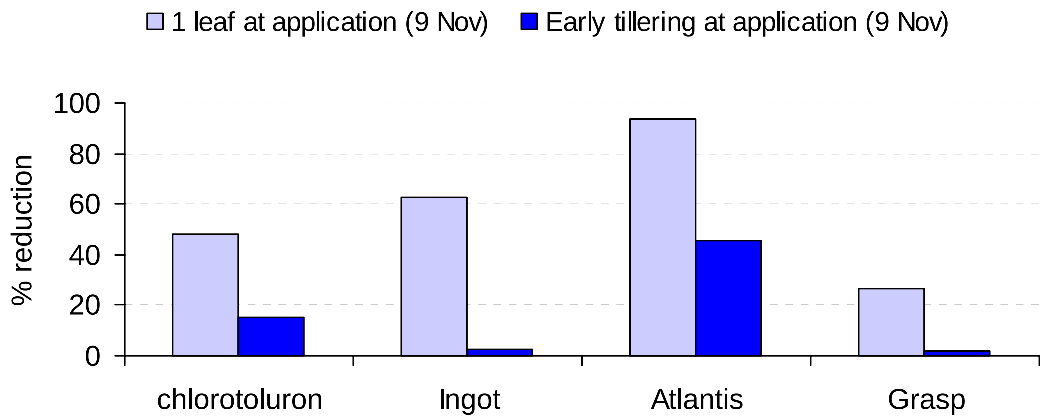

Figure 3. *Percentage reduction of individually labelled Italian rye-grass plants recorded in plots in a commercial field in Essex on 13 January 2006 when treated with a range of herbicides on 9th November 2005 at either the one-two leaf stage or the three-four leaf stage.*

SOIL MOISTURE STATUS AND HERBICIDE ACTIVITY

There was little effect of moisture in the surface layers of the soil on herbicide activity at the time of application where herbicide resistance was not present, provided that it rained within three weeks of application. An exception was Atlantis which provided poor control in dry soil conditions in the autumn of 2002 (Figure 4). This may partly be explained by a delay in weed emergence which would mitigate against the efficacy of this mainly foliage acting herbicide.

All experiments on the impact of soil moisture status on herbicide activity were established with sown non-herbicide resistant Italian rye-grass and control with all herbicides was high. Field experience suggested that the environmental conditions have greater influence on the efficacy of herbicides on resistant rather than susceptible weeds.

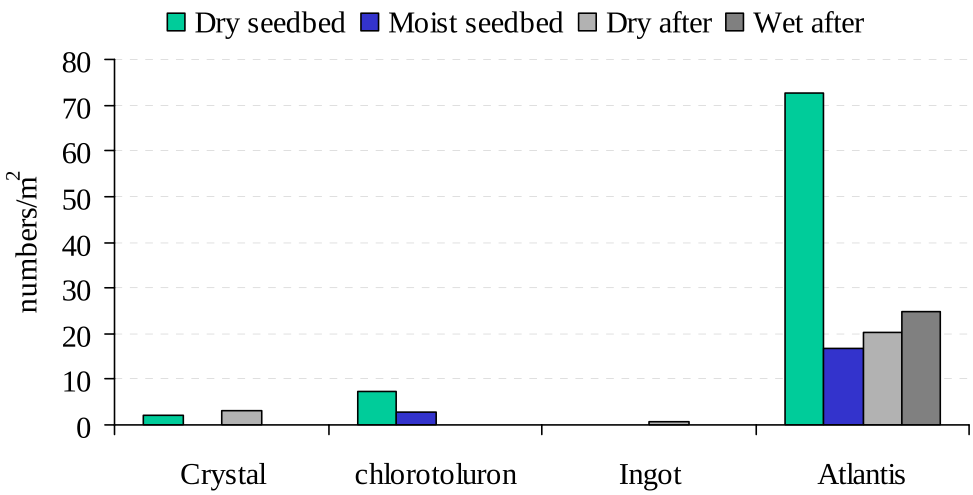

Figure 4. *Number of Italian rye-grass heads/m^2 in June 2003 after applications of a range of herbicides in autumn 2002 either pre-emergence (Crystal, flufenacet + pendimethalin) or when weeds had two leaves. The soil surface layers at the time of application were either dry or wet (rainfall or mist irrigation within a few days prior to application) or conditions after spraying were either dry (no rain for nine days after application) or wet (at least 10 mm of rain or mist irrigation within nine days after spraying).*

The information generated in the project suggests that a sustainable strategy for the control of Italian rye-grass in winter cereals should include:

- Delaying sowing to mid-October where possible in order to exploit the lack of innate dormancy in the weed. A lack of dormancy would also support field observations that inversion tillage reduces populations when compared to non-inversion tillage and that stale seedbeds may encourage the emergence of shallowly incorporated seed prior to sowing.
- Rotating herbicides with different modes of action between years to delay the development of herbicide resistance. The development of resistance to the 'fops'/'dims'/'dens' and the sulfonylureas (such as Atlantis) is a particular risk and reliance on their modes of action should be minimised. Herbicides can be applied at the optimum growth stages of the weed for control in the autumn without the concern of a secondary peak in emergence in the spring.
- Soil moisture status may not reduce the efficacy of herbicides on weed plants that do not contain any resistance mechanism, provided that it rains within three weeks after application. The exception is that the activity of Atlantis may be impaired by dry soil conditions. Soil moisture status may be more important to herbicide activity when the Italian rye-grass is herbicide resistant.

INTRODUCTION

Italian rye-grass (*Lolium multiflorum*) is an annual grass weed of intensive winter wheat rotations, even occurring on farms with no recent history of sowing it as a crop. The number of infestations increased steadily until the introduction of Atlantis (iodosulfuron + mesosulfuron) in 2003. The efficacy of this herbicide masked further population trends.

Whilst Italian rye-grass is not a major weed in winter cereals, it can cause significant control problems on farms where it occurs. An unstructured survey of annual grass weeds in cereals by Farmers Weekly in 1999 highlighted the concern shown by many intensive winter wheat growers over the spread and control of Italian rye-grass. The survey suggested that infestations of this species were expanding rapidly at that time. Indeed, 37% of farms in Southern/Eastern England reported increasing levels of infestation but it is likely that those responding to the survey would have been aware of an annual grass weed problem on their farm.

The weed can move from field-to-field during harvesting and *via* cultivation machinery, and to neighbouring farms on animals, and possibly by wind movement over short distances. It is often resistant to herbicides, the main mechanism being enhanced metabolism but the number of instances of target site resistance to the aryloxyphenoxy-propionates (‘fops’) and cyclohexanediones (‘dims’) appears to be increasing (HGCA Guide 10, Managing and preventing herbicide resistance in weeds). Target site resistance to the recently introduced product Axial (pinoxaden, a phenylpyrazoline) has also been identified by the manufacturer. This herbicide has a similar mode of action (ACCase) to the ‘fops’ and ‘dims’.

Much is known about the agro-ecology of the weed because it is also a major crop species (IGER, personal communication). Field experience by The Arable Group (TAG) agronomists and others suggests that a return to spring cropping for at least 2-3 years will help to eliminate it and also that non-inversion tillage (compared to ploughing) will increase numbers radically in subsequent autumn-sown crops. The latter is not surprising because the weed as a crop is sown in the top few centimetres of soil.

Field experience suggests that persistence of viable seed in the soil is similar to that of black-grass. According to plant breeders, dormancy is low but in some cases prolonged germination in the field has been noted, particularly in association with early drilling. More complete germination takes place in the dark and so it is likely to respond to shallow stale seedbed cultivations.

TAG had already identified the herbicide options for effective control of Italian rye-grass in wheat in trials prior to the start of the project. These are notably flufenacet +/- pendimethalin, applied pre-emergence of the crop and weed, and chlorotoluron, diflufenican + flurtamone + isoproturon, tralkoxydim and iodosulfuron +/- mesosulfuron, applied post-emergence of the crop and weed. The herbicide pinoxaden (Axial) was not introduced until 2005. Weed scientists and manufacturers are concerned that the continued reliance on iodosulfuron +/- mesosulfuron could rapidly lead to target site resistance to the sulfonylurea herbicides.

The key issues regarding effective control in wheat identified by The Arable Group prior to the inception of the project were:

- the impact of time of drilling of winter wheat on the number of Italian rye-grass plants in the crop and the period of their emergence. The available post-emergence herbicides may have to be applied when the weed is very small and significant numbers of Italian rye-grass emerging after the application may result in further herbicide applications being required.
- the prediction of performance of pendimethalin + flufenacet and chlortoluron and diflufenican + flurtamone + isoproturon in order to optimise control and determine whether further herbicide applications may be required. This should minimise reliance on the mode of action of Atlantis and so help to prevent target site resistance to this group of herbicides. Soil moisture has been identified in previous HGCA-funded research as a critical determinant of the performance of herbicides on other difficult to control weeds (Project Report 172 – Defining factors which affect the chemical and cultural control of brome species in winter cereals).

This project tested two hypotheses:

- that time of drilling of winter wheat significantly affects the number of Italian rye-grass plants and their period of emergence in the crop
- that rainfall patterns significantly affect the efficacy of herbicides used for the control of Italian rye-grass

In addition the project had these specific objectives:

a. to measure the impact of drilling winter wheat on a naturally infested site in mid-September, end-September and mid-October on the numbers of Italian rye-grass in the crop
b. to measure the impact of time of drilling on the emergence of weeds
c. to measure the importance of weed size for the efficacy of chlorotoluron and Ingot (diflufenican + flurtamone + isoproturon), Grasp (tralkoxydim) and Atlantis WG (iodosulfuron + mesosulfuron)
d. to measure the importance of seedbed moisture and subsequent rainfall on the control of Italian rye-grass with Crystal (pendimethalin + flufenacet), chlortoluron, Ingot (diflufenican + flurtamone + isoproturon) and Atlantis (iodosulfuron + mesosulfuron)

METHODS

Specific objectives a, b, c

One field trial was carried out in a commercial field on a ploughed medium loam soil for each of the first three years of the project (autumns 2002-2004). The treatments were:

Main treatments:
- drill mid-September
- drill end September
- drill mid-October

Sub–treatments
- herbicides (all at recommended rates):
  - chlorotoluron at 3,500 g/ha (as Tolugan)
  - diflufenican + flurtamone + isoproturon at 101 + 251 + 1500 g/ha (as Ingot)
  - iodosulfuron + mesosulfuron at 2.4 + 12 g/ha (as Atlantis WG)
  - tralkoxydim at 250 g/ha tralkoxydim (as Grasp)
  - untreated control

A split plot design was used with three times of sowing as the main treatments, and herbicide treatments as sub-treatments. There were three replicates. The post-emergence herbicides were applied on the same date, when the rye-grass was typically at the one-leaf stage in the latest sowing and at the three-leaf stage in the earliest sowing. In addition, the periodicity of weed emergence was recorded in twelve quadrats, where emerged weeds were carefully removed by hand at each time of assessment.

There was little or no Italian rye-grass in field experiment in the third year of the project. This was perhaps due to the weed emerging before the wheat was sown: it was noted that there was an emergence prior to sowing when the site was being treated with glyphosate. Hence in autumn 2005, an additional experiment on a clay soil ploughed to around 20 cm was established in a commercial field in Essex. A simpler approach was adopted as it was not possible to achieve differential sowing dates on the site. Fifteen well distributed rye-grass plants, either at the one to two-leaf stage or the three to four-leaf stage, were tagged with different coloured cocktail sticks in each of two quadrats within every plot that was to be treated with the candidate herbicides. Three replicates were used and so a total of 90 plants were tagged at the one to two-leaf stage and 90 at the two to four-leaf stage. The plants were assessed at one month and two months after herbicide application. Later assessment was not possible due to the surviving tagged plants becoming too large and thus proving difficult to separate from neighbouring plants.

Specific objective d

In an experiment, carried out in each autumn from 2002 to 2005 inclusive on the sandy clay loam soil of the Morley Farms, Italian rye-grass seed was broadcast over sites free of the weed prior to the seedbed cultivation and the sowing of winter wheat. A sowing rate of 300 seeds/m^2 was used for the rye-grass and 400 seeds/m^2 for the wheat. The sandy clay loam soil was kept dry before or after spraying by the use of transparent covers and the site was mist irrigated if the soil became too dry. The aim was to spray herbicides with moist or dry soil surface layers at the time of application and alternatively to mimic when it was dry or when there was at least 10 mm of rain or irrigation in the two/three weeks following application. The experiment was a complete randomised block design with three replicates (Photograph).

Photograph. *Experiment on the impact of soil moisture on herbicide efficacy in the autumn of 2002*

The full label recommended doses of the herbicides tested were:

Pre-emergence of crop and weed:

- flufenacet + pendimethalin at 240 + 1200 g/ha (as Crystal)

and the following at the two-leaf stage of the weed:

- chlorotoluron at 3,500 g/ha (as Tolugan)
- diflufenican + flurtamone + isoproturon at 101 + 251 + 1500 g/ha (as Ingot)
- iodosulfuron + mesosulfuron at 2.4 + 12 g/ha (as Atlantis WG)
- untreated control

Percentage reduction of plants in the spring and heads in the summer was recorded in each of the three replicates.

Autumn 2003 was exceptionally dry until the end of October (Appendix 2) and it proved impossible to achieve differential soil moisture conditions. In addition, further pot experiments and field experiments were carried out in the autumn 2006 but failed to establish sufficient differential in soil moisture status.

The wheat in all the experiments was managed according to local good commercial practice, with the exception of herbicides. An application of an herbicide to control annual broad-leaved weeds was made to some sites. Plot size in the wheat crops were 12 metres long and 2.1 metres wide and in the experiments on soil moisture status they were 4.5 metres by 2.1 metres. All herbicides were applied in a total volume of 200 litres/ha through hand held plot sprayers fitted with 11002 conventional flat fan nozzles.

RESULTS

TIME OF EMERGENCE OF THE WEED

Three years of data were collected for the 2002/2003, the 2003/2004 and the 2005/2006 cropping years. The experiment in the cropping year 2004/2005 had extremely low populations of black-grass.

Peak emergence occurred within two to three weeks of the medium loam soil becoming thoroughly moist in the autumns of 2002 and 2003. September and early October 2002 were dry (Appendix 2) but some emergence occurred on the site. Significant rain began to fall from 12th October and peak emergence occurred towards the end of the month (Table 1). However, unlike black-grass and barren brome (*Bromus sterilis*) there was a prolonged 'tail' of emergence, which was recorded until mid-March. The numbers emerging in the spring were similar for all three drilling dates.

	Sowing date 17th September 2002	27th September 2002	11th October 2002
6th October 2002	22.6	*	*
21st October 2002	*	19.9	*
30th October 2002	40.4	*	*
11th November 2002	21.8	*	40.5
11th December 2002	10.3	15.0	9.2
16th January 2003	3.3	6.5	3.3
21st February 2003	0.8	2	1.0
17th March 2003	0.25	1.2	0.5

* = no recording on that date

Table 1. *Emerged rye-grass plants/m^2 since sowing or the previous recording date in plots sown on three different dates in a commercial field in Norfolk, autumn 2002*

Italian rye-grass numbers were lower on a medium loam site in the 2003/2004 season. This resulted in increasing the size of each fixed quadrat for recording emergence to a square metre, each data point being collected from 12 m^2. Hence, it is considered that the data were robust despite plant numbers being low. Soil conditions were extremely dry until the last few days of October (Appendix 2), after which the soil surface layers became thoroughly moist. Taking this into account, the pattern of emergence was similar to the previous year with peak emergence occurring by mid-November, although some emergence was recorded up to the end of April (Table 2). The numbers emerging in the spring were similar or perhaps slightly higher for the later drillings.

The assessment of emergence in the 2005/2006 season was done on a heavy clay soil with high populations of Italian rye-grass. The soil was thoroughly moist when the crop was sown on 20th September and emergence had peaked by 11th October. No emergence was recorded after late March (Table 3).

	Sowing date 19th September 2003	1st October 2003	15th October 2003
18th November 2003	3.8	*	*
27th November 2003	*	1.9	*
9th December 2003	*	*	0.6
18th December 2004	*	*	0.6
19th January 2004	0.2	0.25	0.3
19th February 2004	0.2	0.25	0.3
19th March 2004	0.2	0.6	0.7
30th April 2004	1.2	0.6	0.2

* = no recording on that date

Table 2. *Emerged rye-grass plants/m^2 since sowing or the previous recording date in plots sown on three different dates in a commercial field in Norfolk, autumn 2003.*

	Sowing date 20th September 2005
11th October 2005	50.8
9th November 2005	16.6
16th December 2005	5
13th January 2006	5.8
17th February 2006	6.6
23rd March 2006	3.3

Table 3. *Emerged rye-grass plants/m^2 since sowing or the previous recording date in plots sown in a commercial field in Essex, autumn 2005.*

INFLUENCE OF WEED SIZE ON HERBICIDE ACTIVITY

The sequential sowings on a medium loam site in the autumn of 2002 produced different sized weeds on the day of the application of the herbicides. The results show that the efficacy of tralkoxydim and diflufenican + flurtamone + isoproturon was particularly influenced by weed size. Delaying drilling by one month halved the number of inflorescences of Italian rye-grass in the following summer (Table 4).

Delaying sowing by a month in the following autumn also reduced the number of inflorescences of Italian rye-grass in the plots established on a medium loam site. However, there was not a clear discrimination in the efficacy of the herbicides according to weed size, perhaps due to the very dry conditions to the end of October (Appendix 2) inhibiting emergence, the subsequent very wet soil conditions delaying application until the weeds were larger than in the previous year and to the low weed numbers (Table 5).

Sowing date	Untreated	Tolugan	Ingot	Atlantis*	Grasp*	Mean
17th September 2002	324.0	73.9 (77%)	193.9 (40%)	22.1 (93%)	146.1 (55%)	152.0
27th September 2002	244.8	18.7 (92%)	54.1 (78%)	16.3 (93%)	72.8 (70%)	81.34
11th October 2002	185.1	19.8 (89%)	2.9 (98%)	15.5 (92%)	28.0 (85%)	50.26
						LSD = 77.21
Mean	251.3	37.47	83.63	17.97	82.30	
			LSD = 51.83			
LSD (P=0.05) 101.29						

*Atlantis WG was applied with 1.0 L ha^{-1} of the adjuvant Biopower and Grasp with 0.75 L ha^{-1} of the adjuvant Output

Table 4. *Rye-grass heads/m^2 on 30th May 2003 treated in a total volume of 200 litre/ha with 3,500g chlorotoluron (as Tolugan) or 101g diflufenican + 251g flurtamone + 1500g isoproturon (as Ingot) or 2.4g iodosulfuron + 12g mesosulfuron (as Atlantis WG) or 250g tralkoxydim (as Grasp) on 31st October 2002 when the rye-grass was at the one-leaf stage (crop sown on 11th October), at the one to two-leaf stage (crop sown on 27th September) and at the one to three-leaf stage (crop sown 17th September). All doses are in g a.i./ha and the total volume of application was 200 l/ha. Percent reductions of heads for the specific drilling dates are shown in parentheses.*

Sowing date	Untreated	Tolugan	Ingot	Atlantis*	Grasp*	Mean
19th September 2003	33.52	14.07	19.44	1.85	17.78	17.33
1st October 2003	23.33	12.96	16.67	2.96	9.63	13.11
15th October 2003	15.00	6.67	12.04	0.0	7.41	8.22
						LSD = 4.67
Mean	23.95	11.23	16.05	1.60	11.60	
			LSD = 6.03			
LSD (P=0.05) 10.40						

*Atlantis WG was applied with 1.0 L ha^{-1} of the adjuvant Biopower and Grasp with 0.75 L ha^{-1} of the adjuvant Output

Table 5. *Rye-grass heads/m^2 on 2nd July 2004 treated in a total volume of 200 litre/ha with 3,500g chlorotoluron (as Tolugan) or 101g diflufenican + 251g flurtamone + 1500g isoproturon (as Ingot) or 2.4g iodosulfuron + 12g mesosulfuron (as Atlantis WG) or 250g tralkoxydim (as Grasp) on 3rd December 2003 when the rye-grass was at the two to three-leaf stage (crop sown on 15th October), at the three to five leaf stage (crop sown on 1st October) and at the four-leaf to one tiller stage (crop sown 17th September). All doses are in g a.i./ ha and the total volume of application was 200 l/ha.*

An additional experiment was carried out in the autumn of 2005 on a heavy clay soil. Sequential drilling dates were not possible but instead the fate of weeds of different sizes at spraying was recorded by labelling individuals plants with different coloured cocktail sticks. The site has a high degree of enhanced metabolism resistance and the results of the trial in that particular part of the field also indicated some target site resistance to the 'fops' and 'dims'. The monitoring was carried out until the weeds became too large to discriminate (Table 6).

	Rye-grass on 16th December 2005			Rye-grass on 13th January 2006		
	One to two leaves at spraying					
	Alive	Sick	Dead	Alive	Sick	Dead
chlorotoluron	28.3	19.0	52.7	43.3	8.3	48.4
Ingot	18.9	31.4	49.7	29.1	8.5	62.4
Atlantis*	12.7	39.9	47.8	2.5	3.7	93.8
Grasp*	39.6	34.0	26.4	64.1	9.5	26.5
	Two to four leaves after spraying					
	Alive	Sick	Dead	Alive	Sick	Dead
chlorotoluron	57.8	42.0	0	78.3	6.4	15.3
Ingot	35.1	62.4	2.6	80.8	16.6	2.6
Atlantis*	6.8	56.3	36.8	27.4	26.9	45.6
Grasp*	74.6	17.1	8.3	84.7	13.2	2.1

* Atlantis was applied with 1.0 L ha^{-1} of the adjuvant Biopower and Grasp with 0.75 L ha^{-1} of the adjuvant Output

Table 6. *Percentage of rye-grass plants assessed to be alive, sick or dead one month and two months after treatment on 9th November 2005 at the one to two-leaf stage or at the two to four-leaf stage with 3,500g chlorotoluron (as Alpha Chlorotoluron) or 101g diflufenican + 251g flurtamone + 1500g isoproturon (as Ingot) or 2.4g iodosulfuron + 12g mesosulfuron (as Atlantis WG) or 250g tralkoxydim (as Grasp). All doses are in g a.i./ha and the total volume of application was 200 l/ha.*

The results indicated that size of weed at application is critically important to herbicide efficacy, including Atltantis, on a site with 'very difficult to control' Italian rye-grass. It is important to note that many of the larger weeds that were showing symptoms of damage from Atlantis a month after spraying had recovered by the second assessment two months after spraying. The opposite was true for small weeds at the time of spraying.

SOIL MOISTURE STATUS AND HERBICIDE ACTIVITY

Despite experiments over five seasons, the only experiment to show significant differences was that carried out in the autumn of 2002. This indicated that applying Atlantis when the establishment phase was relatively dry and it remained dry at application resulted in poorer control. This experiment and the others that were carried out in the subsequent years demonstrated that number of inflorescences/surviving plant tended to be higher for Atlantis than for the other herbicides tested (Table 7).

	Crystal		Tolugan 700		Ingot		Atlantis	
	Spring (plants/m^2)	Summer (heads/m^2)	Spring (plants/m^2)	Summer (heads/m^2)	Spring (plants/m^2)	Summer (heads/m^2)	Spring (plants/m^2)	Summer (heads/m^2)
Dry seedbed	0.79	1.97	0.62	7.41	0.00	0.00	3.09	72.84
(untreated/m^2)	(62.96)	(377.16)						
Moist seedbed	0.00	0.00	0.00	2.90	0.00	0.00	0.00	16.77
(untreated/m^2)	(59.74)	(361.65)						
Rain after	0.00	0.00	0.00	0.00	0.00	0.00	2.47	24.69
(untreated/m^2)	(57.41)	(338.27)						
Dry after	1.23	3.09	0.00	0.00	0.00	0.62	0.62	20.37
(untreated/m^2)	(62.96)	(385.80)						

LSD, heads (P=0.05) 34.57

CV%, heads 25.7

Table 7. *Number of rye-grass plants/m^2 on 28th March 2003 or heads/m^2 on 29th May 2003 after treatment with 240g flufenacet + 1200g/ha pendimethalin (as Crystal) applied pre-emergence on 26th September 2002 or with 3,500g/ha chlorotoluron (as Tolugan 700) or 101g diflufenican + 251g flurtamone + 1500g/ha isoproturon (as Ingot) or 2.4g iodosulfuron + 12g/ha mesosulfuron (as Atlantis WG + Biopower) applied when the rye-grass had 2 leaves on 17th October 2002 . All doses are in g a.i./ha. Soil conditions where dry seedbed (no rain in the 10 days prior to spray application) , moist seedbed (where 10 mm rainfall or irrigation occurred within 10 days prior to spray application), rain after (at least 10 mm of rain within 9 days after application) and dry after (no rain within 9 days after application).*

Results were obtained from the experiments in autumn 2003 and 2005 (Appendix 1) but the one established in autumn 2004 had to be abandoned due to extremely wet soil conditions.

DISCUSSION

The advent of the very effective herbicide product Atlantis has masked the problem of herbicide resistance in Italian rye-grass. However, there is concern over development of resistance to its mode of action, which suggests that it would be inadvisable to over-rely on this product or those that share the same mode of action of acetolactate synthate (ALS). This project investigated how to get the best out of alternative herbicides and so provide the basis for a more sustainable herbicide strategy.

The results of this project agreed with the view of grass breeders that Italian rye-grass has little or no innate dormancy by the time winter cereal crops are sown and current research by Rocio Alarcon-Reverte at Rothamsted supports this view. This not only results in peak emergence within two to three weeks of the soil surface layers becoming thoroughly moist but also indicates that delayed drilling can significantly reduce infestations. However, the importance of the surface layers of the soil becoming thoroughly moist could result in a delay in drilling being less successful when the soil remains dry, particularly on clay soils. However, this did not occur in the very dry autumn of 2003 (Tables 2 and 5) on a medium loam soil. The lack of weeds in the time of drilling experiment in autumn 2004 was perhaps due to the fact that the majority of the weeds had germinated in the moist conditions and had begun to emerge by mid-September. The technician over-spraying the site with glyphosate prior to sowing reported that he had noted significant rye-grass emergence.

However, unlike black-grass and barren brome, there appeared to be a prolonged ‘tail’ of emergence throughout the winter and into early spring. Moreover, emergence after mid-November was about the same whether the crop is sown in mid-September or mid-October. Hence, the higher numbers in the earlier drilling were due to emergence prior to mid-November.

Explaining the cause of the prolonged ‘tail’ in emergence is challenging as the weed has little innate dormancy. It has to be speculated that some seeds are subsequently induced or enforced into dormancy.

The time of emergence studies did not confirm the concern amongst some farmers that there is a secondary peak of emergence of Italian rye-grass in the spring leading them to conclude that the weed should be treated with herbicides in the spring rather than the autumn. Current research by Rocio Alarcon-Reverte at Rothamsted is also recording that there is not a secondary peak of emergence in the spring and that the plants that do emerge at this time of year are feeble and do not set much seed. Hence, because the project demonstrated that weeds are more vulnerable to some herbicides when they are very small, it would be inadvisable to delay applications due to concern over the emergence pattern of the weed unless emergence has been severely restricted by dry soil conditions.

The increased relative vulnerability of small weeds to post-emergence herbicides was particularly noted on the site with high levels of resistance. This is in common with the impact of herbicides on resistant black-grass and wild-oats that has been measured in other HGCA-funded research (Topic sheet 46, Dealing with herbicide-resistant wild-oats; Guide 10, Managing and preventing herbicide resistance in weeds).

The impact of the size of Italian rye-grass plants on the efficacy of Atlantis is of particular interest. Differential control was only recorded on the most resistant site where there was a high level of enhanced metabolism resistance. The experiment on this site clearly demonstrated that larger weeds exhibiting symptoms had a higher chance of survival than smaller weeds.

Experiments on the possible impact on efficacy of soil moisture status at the time of application suggested that usually this is not important with weed populations that demonstrate little or no herbicide resistance. Herbicide susceptible populations were purchased for sowing this experiment and the results show that in the absence of resistance a range of herbicides will provide effective control.

However, there was one significant effect. The control achieved by Atlantis was reduced in a dry season for the establishment of Italian rye-grass and when it remained dry at the time of application. This may partly be explained by a delay in weed emergence which would mitigate the efficacy of this mainly foliage-acting herbicide. In addition, the impact was exaggerated by the fact that there were a large number of heads on each surviving plant and it is a matter of speculation that such differences in head numbers may not have occurred if, as recommended on the product label, Atlantis was tank-mixed with another herbicide. However, these data reflect field experience by Arvalis in France and field experience in the UK in the dry spring of 2007 when Atlantis is used alone on large plants. The mode of action of Atlantis is mainly through the foliage and it has been noted in the field that dry conditions also reduce the control of grass weeds achieved by the mainly foliage acting ‘fops’ and ‘dims’ (Xie *et al.*, 1997).

Field experience also suggests that herbicides may be more dependent on soil and weather conditions when used on weeds species that are difficult to control or on weeds that are herbicide resistant. This was demonstrated in TAG experiments on black-grass and in a previous HGCA-funded project on the control of barren brome (Project Report 172, Defining factors which affect the chemical and cultural control of brome species in winter cereals).

The information generated in the project suggests that a sustainable strategy for the control of Italian rye-grass in winter cereals should include:

- Delaying sowing to mid-October where possible in order to exploit the lack of innate dormancy in the weed. A lack of dormancy would also support field observations that inversion tillage reduces populations when compared to non-inversion tillage and that stale seedbeds may encourage the emergence of shallowly incorporated seed prior to sowing.

- Rotating herbicides with different modes of action between years to delay the development of herbicide resistance. The development of resistance to the ‘fops’/‘dims’/‘dens’ and the sulfonylureas (such as Atlantis) is a particular risk and reliance on their modes of action should be minimised. Herbicides can be applied at the optimum growth stages of the weed for control in the autumn without the concern of a secondary peak in emergence in the spring.
- Soil moisture status may not reduce the efficacy of herbicides on weed plants that do not contain any resistance mechanism, provided that it rains within three weeks after application. The exception is that the activity of Atlantis may be impaired by dry soil conditions. Soil moisture status may be more important to herbicide activity when the Italian rye-grass is herbicide resistant.

REFERENCES

H. S. Xie, A. I. Hsiao, W. A. Quick (1997) Influence of drought on graminicide phytotoxicity in wild oat (*Avena fatua*) grown under different temperature and humidity conditions. *Journal of plant growth regulation*, 16, 233-237.

Appendix 1 – results from experiments on soil moisture status and herbicide activity, autumn 2003 and 2005

	Crystal		Tolugan 700		Ingot		Atlantis	
	Spring (plants/m^2)	Summer (heads/m^2)	Spring (plants/m^2)	Summer (heads/m^2)	Spring (plants/m^2)	Summer (heads/m^2)	Spring (plants/m^2)	Summer (heads/m^2)
Dry seedbed	0.60	2.47	0.00	0.00	2.39	10.49	3.59	18.52
(untreated/m^2)	(63.39)	(265.43)						
Moist seedbed	0.60	8.64	0.00	0.00	1.20	3.70	0.60	21.60
(untreated/m^2)	(31.69)	(229.01)						
Rain after	0.00	4.94	2.99	0.00	2.39	13.58	2.39	16.05
(untreated/m^2)	(52.03)	(258.02)						
Dry after	0.00	1.23	2.39	0.00	1.79	2.47	1.79	6.17
(untreated/m^2)	(42.46)	(253.70)						

LSD, heads (P=0.05) 49.77

CV%, heads 54.03

Table 1. *Number of rye-grass plants/m^2 on 11th March 2004 or heads/m^2 on 5th July 2004 after treatment with 180g flufenacet + 900g/ha pendimethalin (as Crystal) applied pre-emergence on 29th September 2003 or with 2,675 g/ha chlorotoluron (as Tolugan 700) or 76g diflufenican + 188g flurtamone + 1,120g/ha isoproturon (as Ingot) or 1.8g iodosulfuron + 9g/ha mesosulfuron (as Atlantis WG + Biopower) applied when the rye-grass had 2 leaves on 13th November 2003 . All doses are in g a.i./ha. Soil conditions where dry seedbed (no rain in the 10 days prior to spray application) , moist seedbed (where 10 mm rainfall or irrigation occurred within 10 days prior to spray application), rain after (at least 10 mm of rain within 10 days after application) and dry after (no rain within 10 days after application).*

	Crystal		Tolugan 700		Ingot		Atlantis	
	Spring (plants/m^2)	Summer (heads/m^2)	Spring (plants/m^2)	Summer (heads/m^2)	Spring (plants/m^2)	Summer (heads/m^2)	Spring (plants/m^2)	Summer (heads/m^2)
Dry seedbed	1.11	3.33	0.00	1.00	3.33	27.11	0.00	1.33
(untreated/m^2)	(48.89)	(272.67)						
Moist seedbed	3.33	8.67	0.00	0.44	6.67	8.33	0.00	0.44
(untreated/m^2)	(43.33)	(270.00)						
Rain after	1.11	0.44	0.00	0.56	0.00	12.67	0.00	0.11
(untreated/m^2)	(16.67)	(227.33)						
Dry after	10.00	23.56	0.00	6.22	2.22	6.89	0.00	0.33
(untreated/m^2)	(72.22)	(288.00)						

LSD, heads (P=0.05) 41.16

CV%, heads 24.94

Table 2. *Number of rye-grass plants/m^2 on 2nd May 2006 or heads/m^2 on 22nd June 2006 after treatment with 120g flufenacet + 600g/ha pendimethalin (as Crystal) applied pre-emergence on 19th September 2005 or with 1,750 g/ha chlorotoluron (as Tolugan 700) or 51g diflufenican + 126g flurtamone + 750g/ha isoproturon (as Ingot) or 1.2g iodosulfuron + 6g/ha mesosulfuron (as Atlantis WG + Biopower) applied when the rye-grass had 2 leaves on 17th October 2005 . All doses are in g a.i./ha. Soil conditions where dry seedbed (no rain in the 10 days prior to spray application) , moist seedbed (where 10 mm rainfall or irrigation occurred within 10 days prior to spray application), rain after (at least 10 mm of rain within 10 days after application) and dry after (no rain within 21 days after application).*

Appendix 2 – weather summaries September and October 2002 and 2003, Morley

September 2002

Date DD MM	Air °C Max	Air °C Min	Air °C Mean	Soil 5 cm Mean	Soil 10 cm Mean	Rain mm	Sun Total hours	Irrad. Mean W/m²	Wind m/s Mean	Wind direct Mean	Grass minimum oC	RH% @0900	Soil 10cm @0900
1 9	19.8	7.0	13.6	18.5	17.1	0.0	4.4	142.3	0.8	41	3.0	67	16.3
2 9	20.9	5.8	13.9	17.9	16.4	0.0	6.5	167.2	1.6	87	2.7	68	15.2
3 9	21.0	11.0	15.6	18.3	16.8	0.4	6.2	156.7	1.6	79	5.8	89	15.7
4 9	21.1	10.4	14.8	18.5	16.9	0.2	3.5	122.9	0.8	42	5.5	100	15.9
5 9	23.0	9.9	16.7	18.5	16.9	0.0	6.1	152.8	1.7	233	4.9	75	15.3
6 9	22.6	14.8	18.1	19.1	17.5	0.4	4.1	133.1	3.6	219	13.9	80	16.8
7 9	20.0	10.4	15.0	18.6	17.0	3.8	3.7	127.5	1.7	214	5.8	97	16.1
8 9	17.8	9.7	13.1	17.2	15.8	3.4	2.3	80.3	1.0	145	5.5	98	14.9
9 9	18.7	7.7	13.7	16.2	14.9	17.2	0.2	36.4	2.6	117	4.9	100	14.0
10 9	19.9	8.4	13.8	17.0	15.6	0.0	9.0	165.3	1.2	229	5.0	85	14.1
11 9	19.0	7.5	14.4	16.7	15.2	0.2	3.8	84.3	1.1	19	4.4	78	14.0
12 9	20.8	14.5	17.0	18.8	17.1	0.0	6.1	148.3	2.1	69	10.3	100	16.0
13 9	21.6	14.1	17.2	19.0	17.3	0.2	7.6	166.6	1.8	53	8.7	83	16.0
14 9	15.9	13.9	14.9	17.7	16.5	0.2	0.0	42.5	1.7	3	12.6	84	16.4
15 9	16.8	9.8	14.2	17.1	15.8	0.0	0.8	83.8	1.3	356	4.1	77	15.3
16 9	16.1	11.7	13.6	16.7	15.2	0.0	0.0	57.8	0.6	355	7.4	84	14.7
17 9	17.4	9.2	14.0	17.1	15.5	0.0	0.0	68.7	0.9	351	4.4	87	14.9
18 9	16.8	11.2	13.6	17.3	15.6	0.0	2.5	104.9	1.1	33	11.5	78	14.7
19 9	17.3	10.5	13.8	17.0	15.4	0.0	2.9	76.9	0.9	42	6.9	88	14.6
20 9	17.6	8.5	13.6	16.8	15.2	0.0	1.6	83.5	0.3	349	3.8	70	14.3
21 9	18.2	9.5	13.7	17.2	15.5	0.0	5.4	137.1	0.9	331	7.9	76	14.1
22 9	15.9	10.7	13.1	16.3	14.9	1.0	4.6	121.2	2.5	339	7.0	90	14.6
23 9	17.1	7.7	12.1	15.1	13.9	0.6	5.5	123.5	1.4	3	3.2	73	13.1
24 9	16.2	6.5	11.2	14.5	13.1	0.0	1.6	78.9	0.9	356	2.1	82	12.2
25 9	17.5	9.7	13.2	15.5	14.0	0.0	6.4	132.4	2.3	295	8.8	86	13.0
26 9	15.0	7.3	11.1	14.5	13.3	3.2	1.8	76.2	1.8	303	2.9	94	13.0
27 9	18.1	3.6	10.7	13.8	12.7	0.0	7.1	129.7	0.6	346	0.8	83	11.1
28 9	19.3	3.8	11.5	14.3	13.3	0.0	6.2	132.4	0.5	161	1.4	89	11.1
29 9	19.7	5.5	12.4	14.8	13.6	0.2	7.3	134.4	1.5	167	2.7	100	12.5
30 9	19.2	5.0	12.8	14.4	13.1	0.2	7.4	113.5	1.4	155	1.1	87	11.9

			Date
Maximum Air Temperature	:	23.0 C	05/09/02
Minimum Air Temperature	:	3.6 C	27/09/02
Minimum Grass Temperature	:	0.8 C	27/09/02
Mean Air Temperature	:	13.9 C	
Number of Air Frosts	:	0	
Number of Ground Frosts	:	0	
Total Rain	:	31.2 mm	
Total Sunshine	:	124.8 hrs	

October 2002

Date DD MM	Air °C Max	Air °C Min	Air °C Mean	Soil 5 cm Mean	Soil 10 cm Mean	Rain mm	Sun Total hours	Irrad. Mean W/m²	Wind m/s Mean	Wind direct Mean	Grass minimum oC	RH% @0900	Soil 10cm @0900
1 10	21.0	6.6	13.6	14.9	13.5	0.0	4.1	97.5	0.6	183	1.4	83	11.8
2 10	18.5	10.6	14.6	15.8	14.2	0.0	0.0	41.7	1.0	192	8.4	100	13.7
3 10	18.4	8.2	14.1	15.8	14.5	0.6	4.9	113.6	1.8	277	1.4	92	14.3
4 10	16.2	6.2	10.6	13.4	12.3	0.2	7.0	111.7	1.4	268	1.5	89	10.7
5 10	17.5	7.5	13.5	14.4	12.9	3.6	0.9	49.9	3.0	284	4.4	87	12.1
6 10	16.2	4.3	11.7	14.3	13.0	0.2	3.9	94.1	1.6	11	0.8	83	12.2
7 10	15.4	4.5	9.9	13.6	12.1	0.0	1.5	74.7	0.5	299	0.8	91	11.3
8 10	11.5	3.6	8.2	11.7	10.2	0.2	0.5	40.1	2.1	102	0.7	95	9.9
9 10	13.6	4.4	9.8	11.2	9.8	0.0	6.5	106.6	3.1	86	0.2	77	8.1
10 10	13.3	10.1	11.6	13.1	11.7	0.0	1.6	68.8	3.2	78	8.4	84	11.2
11 10	11.2	9.5	10.5	12.9	11.3	0.0	0.0	41.4	3.1	101	8.6	83	10.9
12 10	10.3	6.7	9.1	12.2	10.6	10.2	0.0	11.3	1.3	219	3.0	99	10.5
13 10	11.0	2.5	7.9	11.0	9.4	6.2	0.1	45.3	2.0	132	-0.5	100	8.0
14 10	11.6	6.8	10.2	12.1	10.5	9.2	0.1	27.6	2.0	11	2.4	97	10.7
15 10	12.8	7.7	10.2	11.6	10.1	35.0	0.0	14.0	3.8	95	5.2	99	9.6
16 10	10.9	7.0	9.2	11.6	10.3	3.0	0.0	14.5	3.0	311	5.4	98	10.4
17 10	10.8	4.7	7.1	10.0	8.9	0.0	5.6	94.0	2.6	285	2.7	97	7.6
18 10	10.4	2.7	5.7	8.8	7.8	0.4	3.8	79.4	2.5	293	1.9	99	6.7
19 10	10.8	1.1	4.9	7.4	6.6	0.4	8.2	106.0	1.9	265	-1.4	86	4.6
20 10	9.5	-0.5	5.2	8.0	6.8	5.6	0.4	40.5	1.9	120	-3.3	99	5.4
21 10	14.8	8.0	11.3	10.9	9.7	4.2	0.4	25.1	2.5	155	6.7	96	8.9
22 10	15.7	9.5	13.3	13.0	11.7	5.0	0.4	33.3	3.8	189	8.2	98	11.1
23 10	9.8	4.9	7.5	9.7	8.6	0.0	5.1	79.6	4.3	266	2.9	83	8.0
24 10	10.9	1.0	6.9	8.0	7.0	0.0	7.3	90.3	2.8	204	-0.5	87	4.9
25 10	15.0	9.2	11.6	10.9	9.6	4.0	1.4	33.8	4.9	216	7.4	94	9.4
26 10	12.3	8.3	9.6	9.8	8.6	3.0	3.2	66.5	4.5	241	6.0	70	7.7
27 10	15.0	6.6	10.5	10.3	9.1	3.0	0.6	23.0	8.3	249	3.9	76	10.2
28 10	11.5	5.1	7.7	8.6	7.4	0.0	6.0	79.5	2.7	245	3.1	83	6.0
29 10	11.6	4.6	8.3	9.5	8.2	2.0	0.0	18.4	1.5	135	0.4	84	7.6
30 10	11.9	3.9	8.3	9.8	8.5	0.4	1.2	41.2	0.9	19	-0.2	100	6.5
31 10	13.8	5.3	9.3	10.4	9.2	0.0	4.2	61.6	0.9	112	1.4	97	8.6

Maximum Air Temperature	:	21.0 C	01/10/02
Minimum Air Temperature	:	-0.5 C	20/10/02
Minimum Grass Temperature	:	-3.3 C	20/11/02
Mean Air Temperature	:	9.7 C	
Number of Air Frosts	:	1	
Number of Ground Frosts	:	5	
Total Rain	:	96.4 mm	
Total Sunshine	:	78.8 hrs	

September 2003

Date DD MM	Air °C Max	Air °C Min	Air °C Mean	Soil 5 cm Mean	Soil 10 cm Mean	Rain mm	Sun Total hours	Irrad. Mean W/m²	Wind m/s Mean	Wind direct Mean	Grass minimum oC	RH% @0900	Soil 10cm @0900
1 9	17.5	6.6	12.5	15.8	15.6	0.8	4.6	151.3	1.7	326	1.1	83	14.8
2 9	20.4	5.1	12.4	15.5	15.3	0.0	3.8	141.7	0.6	57	1.1	65	14.2
3 9	21.8	4.4	13.9	15.9	15.5	0.0	6.3	150.6	0.8	98	1.3	58	13.9
4 9	23.6	6.1	14.7	16.9	16.5	0.2	10.2	204.7	1.2	132	2.1	64	14.4
5 9	25.1	8.1	16.3	17.3	16.9	0.2	7.4	170.3	1.9	120	3.4	69	15.2
6 9	20.9	9.6	15.4	17.6	17.2	0.2	4.0	133.5	1.5	243	3.4	80	16.5
7 9	18.6	5.4	12.9	16.1	15.9	0.2	6.5	138.2	0.9	199	0.0	75	14.3
8 9	22.1	5.4	12.8	16.3	16.1	0.0	8.5	179.0	0.8	64	1.2	62	14.1
9 9	20.0	7.2	14.0	16.4	16.0	0.0	6.0	155.4	1.7	287	2.7	65	14.9
10 9	14.7	8.9	11.7	15.3	15.3	7.0	0.1	37.5	1.5	326	3.4	100	14.8
11 9	20.4	5.7	13.4	15.1	14.9	1.0	5.4	137.5	1.3	250	1.2	97	13.1
12 9	18.4	7.2	13.6	15.9	15.6	0.2	7.9	149.1	1.4	338	1.2	76	14.4
13 9	22.4	4.7	13.4	15.4	15.1	0.2	10.0	181.7	1.5	173	0.5	82	13.1
14 9	24.7	8.9	16.0	16.0	15.7	0.0	10.2	185.8	1.8	172	3.0	71	14.1
15 9	23.9	8.7	15.5	15.9	15.6	0.0	6.0	133.0	0.7	207	2.8	66	14.2
16 9	26.8	7.9	16.2	16.1	15.8	0.0	9.7	169.3	0.7	232	3.0	72	13.8
17 9	26.6	8.2	17.3	16.5	16.1	0.2	10.3	177.1	1.7	190	2.6	67	14.0
18 9	21.7	8.9	16.4	16.5	16.2	0.0	9.4	165.6	1.9	216	3.3	80	14.3
19 9	23.2	12.0	17.1	17.3	16.9	0.0	9.7	166.7	1.7	215	6.2	70	15.2
20 9	25.8	8.7	17.1	17.1	16.7	0.0	9.3	156.5	1.3	204	4.0	80	14.6
21 9	24.4	8.7	17.4	17.6	17.2	0.0	7.7	141.2	1.8	194	4.6	71	15.2
22 9	22.5	8.0	14.3	16.4	16.2	5.0	3.0	89.2	3.3	243	6.0	82	15.9
23 9	13.6	2.3	8.2	12.7	12.9	0.4	8.2	153.5	2.3	295	-2.9	76	11.9
24 9	17.3	0.4	8.5	11.7	11.8	0.0	10.4	164.6	0.8	216	-4.0	81	9.6
25 9	19.0	2.1	10.1	12.4	12.4	0.0	7.3	141.4	1.1	149	-1.7	69	10.6
26 9	16.6	4.3	10.4	12.1	12.1	0.8	1.8	74.3	1.3	260	-0.0	90	10.7
27 9	16.7	3.5	10.8	12.6	12.5	0.2	6.1	127.6	1.0	3	-0.6	96	10.4
28 9	14.6	5.6	10.5	12.7	12.7	2.4	2.3	69.8	1.0	341	0.1	98	12.3
29 9	17.4	2.8	10.5	11.6	11.5	0.2	9.4	146.8	1.6	217	-0.6	89	9.5
30 9	19.8	6.1	12.0	12.2	12.2	0.0	5.5	115.2	2.1	132	0.4	87	10.7

				Date
Maximum Air Temperature	:	26.8	C	16/09/03
Minimum Air Temperature	:	0.4	C	24/09/03
Minimum Grass Temperature	:	-4.0	C	24/09/03
Mean Air Temperature	:	13.5	C	
Number of Air Frosts	:	0		
Number of Ground Frosts	:	6		
Total Rain	:	19.2	mm	
Total Sunshine	:	206.9	hrs	

October 2003

Date DD MM	Air °C Max	Air °C Min	Air °C Mean	Soil 5 cm Mean	Soil 10 cm Mean	Rain mm	Sun Total hours	Irrad. Mean W/m²	Wind m/s Mean	Wind direct Mean	Grass minimum oC	RH% @0900	Soil 10cm @0900
1 10	18.6	7.2	12.4	12.6	12.5	0.0	6.4	132.0	2.0	41	2.2	82	11.0
2 10	16.8	5.3	12.2	12.0	12.0	0.2	1.7	48.2	1.4	64	0.2	81	10.7
3 10	17.2	9.4	13.7	13.3	13.1	0.2	0.2	55.2	1.6	299	6.8	92	12.7
4 10	13.3	5.8	9.0	11.3	11.4	2.8	6.9	119.2	3.0	305	3.5	69	10.1
5 10	11.1	4.4	7.5	9.8	10.0	1.2	7.4	129.7	3.4	290	-1.5	82	8.7
6 10	14.1	7.1	10.5	10.3	10.3	2.0	3.5	87.7	4.5	261	6.3	80	9.8
7 10	12.7	5.2	8.9	9.5	9.6	4.8	7.4	125.3	4.6	293	2.8	75	8.8
8 10	16.5	3.2	10.6	9.4	9.4	0.4	0.1	29.1	3.3	271	1.6	98	7.8
9 10	18.7	10.0	14.8	12.4	12.1	0.0	5.0	102.4	3.0	264	5.9	80	11.1
10 10	16.8	7.0	13.1	12.5	12.4	0.0	3.8	87.4	3.0	275	2.0	71	12.2
11 10	16.0	5.8	10.5	11.1	11.1	0.0	8.4	118.8	1.4	291	0.9	74	9.6
12 10	15.9	3.8	10.5	10.6	10.7	0.0	3.4	78.7	3.0	101	-0.1	73	9.3
13 10	15.7	9.1	11.5	10.8	10.8	0.0	5.4	88.6	3.8	93	5.0	73	10.0
14 10	15.1	8.7	11.3	10.6	10.6	0.0	8.2	120.6	4.8	92	5.5	73	9.6
15 10	14.2	6.4	9.9	9.6	9.8	0.0	9.0	116.7	3.6	81	1.2	67	8.4
16 10	14.1	6.2	9.5	9.2	9.3	0.0	9.0	112.2	3.0	75	-0.1	75	8.0
17 10	13.3	5.4	8.8	8.6	8.8	0.2	8.9	110.1	3.2	74	-1.4	76	7.4
18 10	13.7	2.4	7.8	8.0	8.2	0.2	6.9	93.0	1.6	53	-2.8	87	6.8
19 10	12.3	1.4	7.7	7.7	7.9	0.2	0.4	30.2	1.3	25	-4.1	92	6.7
20 10	10.7	5.2	7.3	7.7	7.8	1.0	2.7	62.8	2.1	2	2.2	74	7.0
21 10	11.0	-2.2	4.3	6.9	7.1	0.4	3.4	69.3	1.3	337	-6.0	84	6.0
22 10	10.6	-2.2	5.0	6.3	6.5	1.2	1.1	49.5	2.3	87	-5.5	99	5.4
23 10	9.6	-0.9	4.8	6.3	6.5	0.8	5.7	77.0	2.5	42	-5.3	66	5.6
24 10	8.1	-0.6	4.2	5.5	5.7	4.0	1.6	44.5	2.5	303	-5.2	90	4.9
25 10	10.3	1.2	5.6	5.8	5.9	2.6	6.3	79.4	3.0	280	-0.6	85	4.1
26 10	11.1	0.8	6.0	6.5	6.6	1.6	5.4	76.0	1.6	333	-3.4	95	5.6
27 10	11.2	-0.1	4.6	5.7	5.9	0.0	6.9	85.9	0.8	225	-3.3	100	4.4
28 10	10.9	-0.0	5.4	5.9	5.9	3.0	5.1	68.2	1.5	217	-4.1	92	4.3
29 10	8.3	2.4	6.0	6.9	6.9	4.8	0.0	14.8	2.1	233	-0.8	99	6.7
30 10	9.3	2.2	6.2	6.6	6.6	0.4	1.7	40.0	2.6	186	1.1	100	5.9
31 10	10.2	7.5	8.5	8.2	8.1	9.2	0.0	18.2	2.4	250	6.5	100	7.5

			Date
Maximum Air Temperature	:	18.7 C	09/10/03
Minimum Air Temperature	:	-2.2 C	21/10/03
Minimum Grass Temperature	:	-6.0 C	21/10/03
Mean Air Temperature	:	8.6 C	
Number of Air Frosts	:	6	
Number of Ground Frosts	:	15	
Total Rain	:	41.2 mm	
Total Sunshine	:	142.0 hrs	