THE EFFECT OF GLYPHOSATE TREATMENT ON THE GERMINATION POTENTIAL OF RESULTANT CROPS

G McLaren and R Don

Scottish Agricultural Science Agency
East Craigs, Edinburgh, EH12 8NJ

Summary: The use of glyphosate in barley crops has increased by 275% in the last three seasons and this has been accompanied by an increase in the number of samples showing reduced germination with negatively geotropic seedlings. Experimental preharvest treatment of Derkado barley crops with glyphosate resulted in decreased levels of germination. The decrease was greatest in paper towelling medium. Germination in potting compost reduced the levels of glyphosate-induced abnormalities. Reductions in seed germination due to preharvest glyphosate treatments was related to rainfall experienced in the period after spraying and this masked any effect due to crop maturity.

INTRODUCTION

During the seasons 1999/2000 and 2000/2001 there was an increase in the number of barley samples submitted to the Official Seed Testing Station for Scotland (OSTS) showing glyphosate symptoms in germination tests. The paper towelling (PT) germination method (Anon., 1999) provides conditions that are conducive to the expression of chemical damage caused by glyphosate. The main symptoms expressed are: negative geotropism, where roots grow upwards and are often splayed; stunted roots; and the absence of root hairs. Coleoptiles are also affected and can be empty, twisted, stunted or split. To obtain a more accurate assessment of germination potential, samples showing 5%, or more, glyphosate symptoms are retested using Levington's potting compost. This germination method is more expensive and time consuming.

Glyphosate is a herbicide used for the control of perennial weeds such as *Elytrigia repens* L. (couch grass) in cereal grain crops and is increasingly being used as a preharvest desiccant. It is transported throughout the target plant where it acts on various enzymes, inhibiting amino acid metabolism in the shikimic acid pathway (Anon., 1996). The whole plant dies gradually over a period of a few days to several weeks. Glyphosate should not be used as a desiccant where the crop grain moisture is greater than 20% and the manufacturer does not recommend it for use in seed crops (Don *et al.*, 1990; Anon., 1998). Over the last 3 seasons there has been increased anecdotal evidence of its use on certification crops, which is against recommendations of the UK certifying authorities.

The aims of this study were: (1) to investigate the extent of glyphosate germination problems in seed samples intended for further multiplication; and (2) to evaluate the effect of glyphosate application at different stages of crop maturity.

MATERIALS AND METHODS

Survey

The results of all barley samples submitted to the OSTS, Scotland, for germination were examined in 1998/1999, 1999/2000 and 2000/2001. The number of samples showing glyphosate symptoms each season was recorded.

Field Experiment

Twelve 5 x 2 metre plots were marked out in a field of commercial Derkado barley at Gogarbank Farm, Edinburgh. At regular intervals throughout the growing season, ears were randomly sampled and the ear moisture content determined (Anon., 1999). When moisture contents of 50%, 40%, 30%, 25% and 20% were reached, 2 plots were sprayed. One plot was sprayed with glyphosate (Roundup® Biactive™), at the recommended rate of 4 litres/hectare, and the other, control plot, with water. Before harvest, the remaining 2 plots were sprayed. The plots were harvested using a Wintersteiger Nursery Master plot combine and samples for laboratory tests obtained using a Boerner divider (Anon., 1999). Replicates of 4 x 100 seeds from plots sprayed with glyphosate were tested for germination using PT and proprietary potting compost. Samples from control plots were tested using PT only. Seedling assessments were made according to International Seed Testing Association Rules (Anon., 1999).

RESULTS

Survey

The number of samples showing glyphosate symptoms during 1998/99 was low (2%) but there was a dramatic increase in 1999/2000, where 20% of samples showed symptoms. Although higher than 1998/1999 the percentage of samples with glyphosate symptoms in 2000/01 (11%) was lower than 1999/2000 (Figure 1).

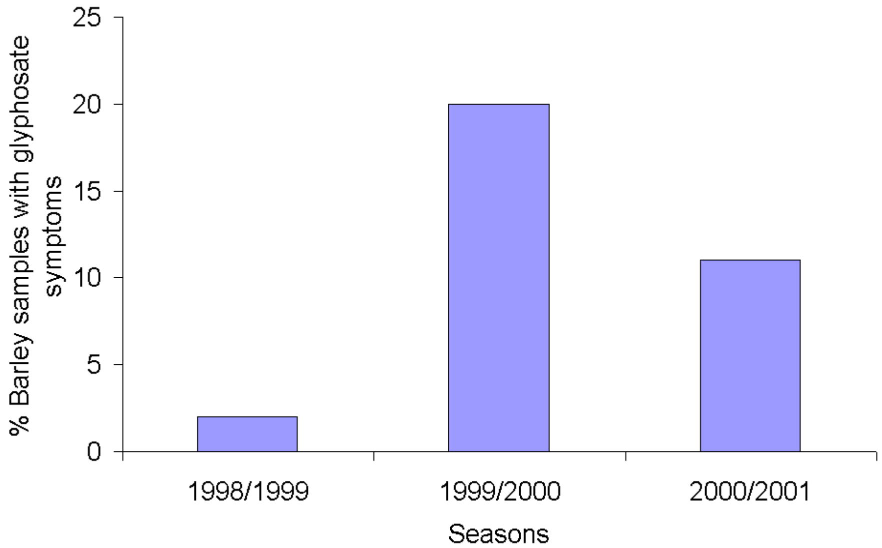


Figure 1. The percentage of barley samples submitted to OSTS in 1998/2001 for germination tests exhibiting glyphosate symptoms

Field Experiment

The results from the field experiment (Table 1) show that spraying with water at different ear moisture contents did not affect the germination and there were no significant differences between the controls. The mean results from the paper towelling tests conducted on samples of seed from plots sprayed with glyphosate are significantly lower than those tested in compost (p=0.05). The mean compost result was statistically similar to that of the control (p=0.05).

Table 1
The effect of glyphosate on germination of Derkado barley sprayed at different moisture contents

% CROP MOISTURE	% GERMINATION GLYPHOSATE SPRAYED PLOTS		WATER SPRAYED PLOTS
	PAPER TOWELLING	COMPOST	PAPER TOWELLING
50	81	79	92
40	85	91	89
30	71	88	91
25	87	92	94
20	83	90	91
Preharvest	93	97	93
Mean	83	90	92
LSD $_{(P=0.05)}$ = 6.81			

When the germination results were examined in detail, it was evident that the difference in the PT and compost germination assessments was due to higher levels of glyphosate-induced abnormalities in the PT tests (Figure 2).

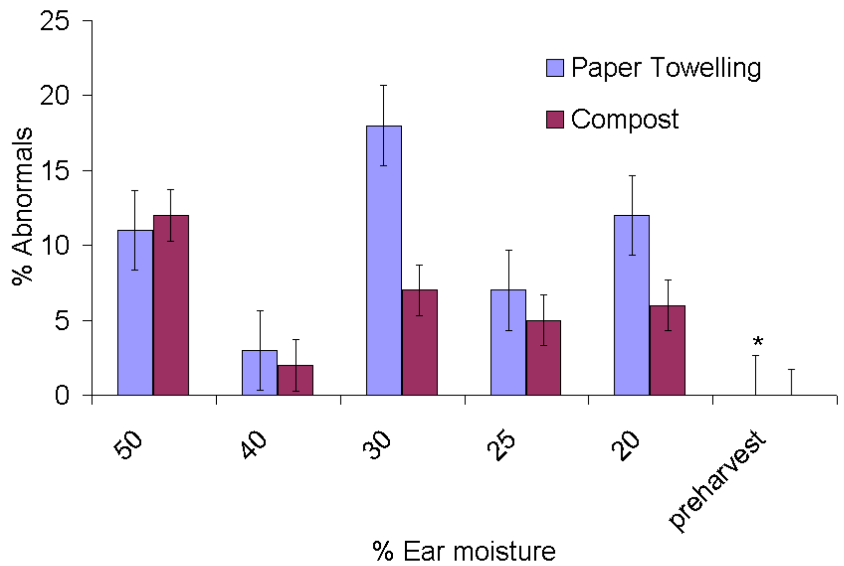


Figure 2. The percentage of abnormal seedlings showing glyphosate symptoms in both PT and compost germination tests of seed obtained from plots sprayed with glyphosate at different ear moisture contents

The average number of glyphosate-induced abnormalities found in paper towelling was 9%. This reduced to 5% when compost was used. There were significant differences between plots, with the number of glyphosate-induced abnormalities being highest in plots sprayed at 50% and 30% moisture contents (Figure 2). When the percentage of glyphosate-induced abnormalities were added to the percentage of normal seedlings, the results were very similar to the control results and are within the limits of variation ($p = 0.05$). The plots sprayed preharvest, and the control plots sprayed with water, showed no glyphosate symptoms.

There was no relationship between the number of glyphosate-induced abnormalities and the moisture content of the ears at the time of spraying. The mean percentage of glyphosate-induced abnormalities was highest at an ear moisture content of 30%. The mean percentage of glyphosate-induced abnormalities at 20% ear moisture content, was higher than that at 40% and 50% ear moisture content (Figure 2).

DISCUSSION

The results from the field experiment clearly demonstrate that glyphosate has a detrimental effect on the germination of seed from crops treated before harvest. The reduction in germination in such crops can be minimised if the seed is tested in compost rather than the paper towelling, which is the standard germination medium. The results contradict those of Don *et al.* (1990) who demonstrated a clear relationship between crop maturity and timing of the glyphosate spraying – greatest damage being caused in crops with the highest moisture content. In this study, no such relationship was found and damage at 20% crop moisture content was significantly greater than that found at 40%.

The summer of 2000 was particularly wet and examination of the rainfall levels experienced at the Gogarbank Automated Meteorological Station indicated that in all but two of the spraying dates (50 % and 30%) were followed immediately by a period of rain (Figure 3). On the days the 50%, 25%, 20% and preharvest moisture plots were sprayed; no rainfall was recorded. 0.2mm of rainfall was recorded on the day the 40% moisture plot was sprayed and 0.8mm on the day the 30% moisture plot was sprayed.

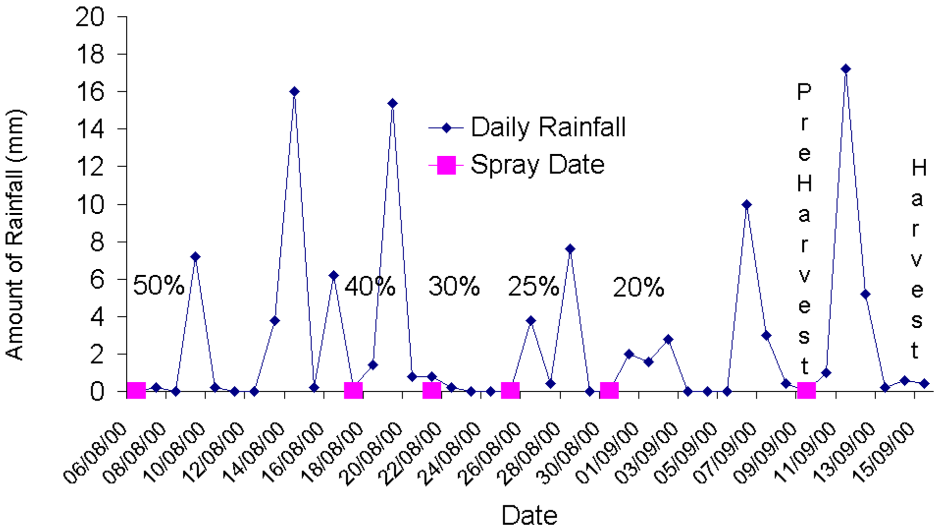
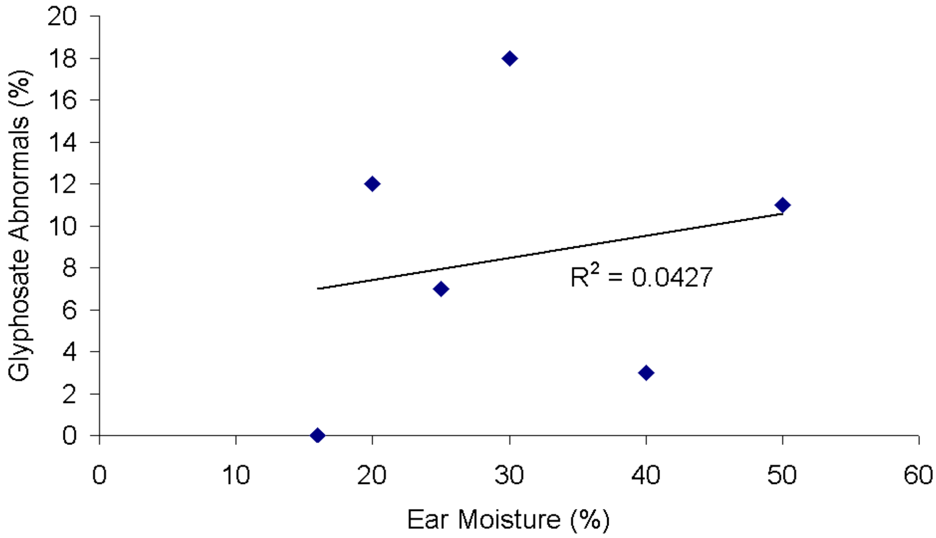


Figure 3. Amount of rainfall[1] occurring at Gogarbank during the glyphosate field trial

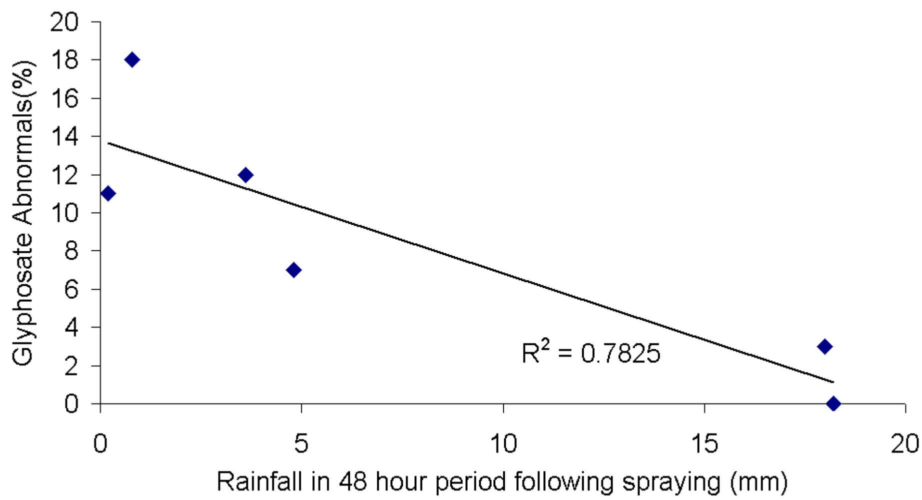
[1] Courtesy of the Meteorological Office

Glyphosate is readily water soluble with the manufacturer recommending that a rain free period of 6 and preferably 24 hours should follow application (Anon., 1998). It was only the 50% and 30% sprayings that conformed to this recommendation and it was seed from these sprayings that showed the greatest levels of damage. In the case of the 40% spraying, this was followed by a period when 16mm of rain fell and the preharvest spray was followed by 23mm of rain. The 40% spraying and preharvest spraying had the lowest level of glyphosate damage.

It would appear that levels of glyphosate damage are most closely related to the level of rainfall experienced in the period immediately after spraying, as shown in figures 4 (a) and (b). There is no significant relationship between ear moisture content and the level of glyphosate-induced abnormalities, whereas, these are significantly related to levels of rainfall in the immediate post spraying period.



(a)



(b)

Figure 4. The relationships between glyphosate abnormal seedlings and (a) ear moisture content at time of spraying and (b) amount of rainfall in the 48 hour period following spraying

The levels of glyphosate-induced abnormalities were lower when samples are tested in compost. It is known that glyphosate is absorbed by the soil matrix and is inactivated. When comparing compost and paper towelling methodologies, greater quantities of water are used in compost tests. A combination of absorption of glyphosate by compost constituents and leaching from the surface of the seed are likely to lead to the greater germination in compost. However, compost testing does not lead to the elimination of glyphosate induced abnormal seedlings. There would appear to be two separate effects of glyphosate treatment:

- A surface effect – this is caused by residual glyphosate from the spraying and can be removed by washing or germination in compost. Similar types of abnormal seedlings can be obtained by germinating barley in a media containing glyphosate (unpublished).
- A physiological effect – the glyphosate has a direct biochemical effect on the seed. This effect is not reversible and no improvements will occur when seed is tested in compost.

The increase in samples exhibiting glyphosate symptoms in germination tests is related to a substantial increase in the use of glyphosate in barley crops. In 1998, 4% of the winter barley and 5% of the spring barley crop was sprayed with glyphosate (17,015 ha in total) (Snowden and Thomas, 1998). In 2000, there was an increase of 275% in the total area sprayed (63,755 ha), with 32% of the winter crop and 17% of the spring crop treated (Kerr, J. 2000, personal communication). This increased use coincides with a halving of the cost of glyphosate.

This investigation is being repeated to confirm the relationship between climatic conditions and the effect of glyphosate treatment. Attempts are also being made to elucidate the differences between the surface and physiological effects of glyphosate treated seed and this involves an examination of the performance of glyphosate affected seed in the field.

ACKNOWLEDGEMENTS

We would like to thank the staff of OSTS and Gogarbank Farm, SASA for their invaluable contribution to this work. We would also like to thank Valerie Cockerell for her assistance in the drafting of this paper.

REFERENCES

Anon., 1996. Glyphosate Fact Sheet. Pesticide News, 33.

Anon., 1998. Roundup Biactive Product Guide, Monsanto plc

Anon., 1999. International Rules for Seed Testing, Rules 1999. Seed Science and Technology, 27.

Don, R; Bartz, J; Bryant, G.F.M; Geffen A.v; Lunn, G; Overaa, P; Steiner, A.M (1990). Germination and tetrazolium testing of treated barley seed samples from glyphosate treated crops in seven ISTA stations. Seed Science and Technology 18, 641 651.

Snowden, J.P; Thomas, L.A (1998). Arable Crops 1998. Pesticide Usage in Scotland Report. Edinburgh: Scottish Agricultural Science Agency.