Aspects of Applied Biology **127**, *2014*
Crop Production in Southern Britain: Precision Decisions for Profitable Cropping

Potential for controlling *Alopecurus myosuroides* (black-grass) using tractor mounted burners on cereal stubbles

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Summary

The objective was to quantify the effect of burning stubble with a tractor mounted infra-red burner on *A. myosuroides* establishment, both pre-drilling, and within a subsequent winter wheat crop. The burner generated temperatures of 480 to 600ºC. Burning significantly reduced the number of weed seedlings emerging compared with the unburnt control. The most significant result was that control by burning was better when assessed within the wheat crop compared with prior to drilling. Where seeds were applied eight days prior to burning, the mean % reduction in *A. myosuroides* plant numbers, relative to unburnt plots, was 37% when assessed 26 days after burning, just prior to sowing wheat. In contrast, the level of control was substantially higher (89–90%) when assessed in the wheat crop in November and January. This beneficial effect almost certainly reflects the dormancy-breaking effect of burning on some of the seeds damaged, but not actually destroyed, by burning.

Key words: Straw burning, stubble burning, black-grass, *Alopecurus myosuroides,* IWM, herbicide resistance

Introduction

Disposing of cereal straw by burning in the field was once a very widely used practice – it has been estimated that straw or stubble was burnt on 55% of the winter cereal area of England in 1977 (Elliott *et al*., 1979). However, the practice has been banned in England and Wales since 1993 (Anon., 1993) largely for environmental reasons. Prior to the ban it was recognised that straw burning had a valuable role to play in weed control and a considerable amount of research was conducted to quantify the benefits. On fields with natural infestations, straw burning killed between 40–80% of *Alopecurus myosuroides* (black-grass), 40–97% of *Bromus sterilis* (sterile brome) and an average of 38% of *Avena fatua* (wild-oats) and 81% volunteer wheat seeds (Wilson & Cussans, 1975; Froud-Williams, 1983; Moss, 1983; Cussans *et al*., 1987). Detailed studies with *A. myosuroides* showed that burning had three distinct effects (Moss, 1980).

1. Many seeds lying on the soil surface were killed, but protection was conferred by even a very shallow (2 mm) covering of soil. The larger the amount of straw burnt, the higher the temperature reached and the greater the kill. Typically 700–800°C is reached within the swath and 270°C max at the soil surface below the swath.

2. The dormancy of many surviving seeds was reduced, including those shallowly buried, which resulted in more rapid seedling emergence subsequently compared with seeds on unburnt stubbles.
3. The environment for weed seed germination was better after burning, possibly because toxins produced by decaying straw on unburnt land affected seed germination and development (Lynch & Harper, 1977).

The overall effect was dependent on the relative influence of these three factors, which varied between fields, but one of the most obvious visible consequences of straw burning was a much earlier flush of autumn germinating *A. myosuroides* seedlings. This is beneficial, as the more weed seeds that germinate on stubbles in early autumn, the fewer remaining to produce seedlings within the next crop. In three successive years, Moss (1981) found a much greater reduction in *A. myosuroides* infestation in winter wheat on burnt, compared with unburnt, plots than was recorded prior to drilling. Hence, the beneficial effects of straw burning at reducing weed populations within the subsequent crop were even greater than it appeared pre-drilling.

The Association of Independent Crop Consultants (AICC) has requested that the ban on straw burning be reviewed and this was the subject of a forum at Cereals 2013. A major justification was the potential to help control *A. myosuroides*, which continues to be a major problem for arable farmers due to increasing herbicide resistance (Hull *et al*., 2014). It is unlikely that the ban on burning cereal straw in fields will be lifted, but a tractor mounted burner might be an acceptable alternative.

The objective of this study was to quantify the effect of burning stubble with a tractor mounted infra-red burner on *A. myosuroides* establishment, both pre-drilling, and within the subsequent winter wheat crop.

Materials and Methods

Design and methodology

A field trial was set up in early September 2013 on a weed-free area after baling winter wheat straw on a Greinton fine sandy loam soil at Fenswood Farm, Long Ashton near Bristol. Seeds of *Alopecurus myosuroides* (4000 m^{-2}), harvested in 2013 and obtained from Herbiseed (New Farm, Mire Lane, West End, Twyford, RG10 0NJ), were applied to two 4 x 2 m subplots within 12 m × 3 m main plots. The % germination of the seed sample used, based on a glasshouse pot test set up the same day seed was spread in the field, was 54%. A randomised block design was used for the field experiment with four replicates. The four main plot treatments consisted of no burning and three speeds of burner operation (0.4, 0.8 and 1.2 km h^{-1}). *Alopecurus myosuroides* seeds were applied to separate, randomised, sub-plots on two seeding dates: 3 September, 8 days prior to burning; or on the morning of burning. Applying seeds to the soil surface immediately prior to burning provides ideal conditions for assessing the effect of burning whereas applying seeds several days earlier, allows them to be washed into the surface soil which more closely mimics natural field conditions.

Plots were burnt on 11 September using a prototype tractor mounted propane gas fired burner based on a ‘Greenburner’ designed by Thermoweed but with infra-red burners constructed to deliver maximum heat to a 1 m wide strip of the soil surface. Speeds were set on the tractor and not verified by measurement. At 27 days after burning, the trial site was sprayed with glyphosate to kill seedlings and 2 days later was cultivated with one pass of a spring tine cultivator to a depth of 6 to 8 cm and sown on 11 October with winter wheat.

Weed assessments

Assessments of *Alopecurus myosuroides* plants were made on 7 October, 26 days after burning, prior to spraying off with glyphosate and cultivation, and subsequently in the wheat crop on 18

November and 28 January, 38 and 136 days after sowing respectively. Assessments were made in two 0.5 m^2 quadrats per sub-plot, placed on the centre of the burnt area.

Results

Burner performance

The burner generated temperatures of 480 to 600ºC, assessed by spot measurements with a hand-held probe. Even at the highest forward speed complete destruction of stubble was achieved and there was little visible difference between the three speeds of operation. However the burners did cut out a few times during operation, apparently due to a lack of air once the heads became too hot. Being a prototype machine, no provision was made for containing the burn and, for this trial, three people were stationed to beat out any flames to prevent burning extending beyond the plot. In any commercial machine, maintaining a controlled burn would be essential.

A. myosuroides plant emergence on 7 October, 26 days after burning (prior to sowing wheat)

A clear effect was observed by 26 days after burning and prior to spraying off with glyphosate and cultivation (Table 1). Burning significantly reduced the number of seedlings emerging compared with the unburnt control. However, significantly more plants emerged on burnt plots where seed was applied eight days prior to the burn compared to the day of burning ($P \leq 0.001$). Averaged across the two sowing dates, there was no difference in seedling number between the three forward speeds.

Table 1. *Mean number of* A. myosuroides *seedlings per 0.5 m^2 (± SE) 26 days after burning*

	Forward speed of burner (km h^{-1})			
Seeding date	No burn (control)	0.4	0.8	1.2
8 days pre-burn	114.3 ± 7.8	64.3 ± 6.4	77.9 ± 8.5	72.9 ± 5.8
Day of burn	127.9 ± 11.0	32.9 ± 6.0	27.4 ± 4.9	46.5 ± 1.2
$LSD_{0.05}$	Seeding date × speed = 18.0			

Proportionally, there was a greater reduction in seedling numbers (mean 72%) where seeds were applied on the day of burning compared to where seeds were applied eight days before burning (mean 37%) (Table 2).

Table 2. *Mean % reduction in number of* A. myosuroides *seedlings, compared to unburnt control plots, assessed 26 days after burning*

	Forward speed of burner (km h^{-1})			
Seeding date	0.4	0.8	1.2	mean
8 days pre-burn	44%	32%	36%	37%
Day of burn	74%	79%	64%	72%

A. myosuroides plant emergence on 18 November, 38 days after sowing wheat

Seedling numbers were, on average, 63% lower on unburnt plots compared to those recorded prior to sowing wheat, but the densities on burnt plots were relatively even lower (Table 3). Consequently, levels of control achieved by burning were higher than those recorded at the pre-sowing assessment (Table 4). At this assessment, neither date of applying weed seeds nor speed of burning had a significant effect on seedling number.

Table 3. *Mean number of A. myosuroides seedlings per 0.5 m^2 ($\pm$ SE) in the wheat crop, 38 days after sowing*

	Forward speed of burner (km h^{-1})			
Seeding date	No burn (control)	0.4	0.8	1.2
8 days pre-burn	39.3 $\pm$ 2.6	3.6 $\pm$ 1.1	5.1 $\pm$ 0.6	3.6 $\pm$ 1.0
Day of burn	51.4 $\pm$ 8.0	3.4 $\pm$ 0.5	2.6 $\pm$ 0.7	2.9 $\pm$ 0.7
$LSD_{0.05}$	Seeding date × speed = 8.9			

Burning treatments achieved 87 to 94% reduction in black grass number in the wheat crop compared to unburnt areas (Table 4). The mean levels of control were substantially higher than those recorded prior to sowing: 90% *vs* 37% where seeds applied 8 days before burning; and 94% *vs* 72% where seeds applied on day of burning (Tables 2 and 4).

Table 4. *Mean % reduction in number of* A. myosuroides *seedlings, compared to unburnt control plots, assessed 38 days after sowing wheat*

	Forward speed of burner (km h^{-1})			
Seeding date	0.4	0.8	1.2	mean
8 days pre-burn	91%	87%	91%	90%
Day of burn	93%	95%	94%	94%

Assessments of *A. myosuroides* seedlings made at the end of January 2014 were very similar to those recorded in mid-November 2013, with a mean seedling density per 0.5 m^2 on unburnt control plots of 38.7 ± 1.7 where seeds were applied eight days prior to burning and 47.5 ± 8.7 where seeds were applied on day of burning. The mean % reductions achieved by burning were 89% and 93% respectively.

Discussion

This trial showed that controlled stubble burning with the tractor mounted prototype infra-red burner could achieve a high level of control of *A. myosuroides* seeds lying on, or close, to the soil surface. The density of weed plants in a subsequent wheat crop, established after an application of glyphosate and tine cultivation, was further reduced to less than 10 plants per m^{-2} compared to about 80 to 100 plants per m^{-2} where no burning was used.

The most significant result was that control by burning was much better when assessed within the wheat crop compared with prior to drilling. Where seeds were applied 8 days prior to burning, the mean % reduction in *A. myosuroides* plant numbers, relative to unburnt plots, was 37% when assessed 26 days after burning, just prior to sowing wheat. In contrast, the level of control was substantially higher (89–90%) when assessed in the wheat crop in November and January. These values are remarkably similar to those obtained by Moss (1981) in an experiment where 6 t straw ha^{-1} was burnt in-field on 18 August 1976; a 41% reduction when assessed pre-drilling but a, much better, 91% reduction when assessed in December within a wheat crop direct drilled on 22 October.

This beneficial effect almost certainly reflects the dormancy-breaking effect of burning on some of the seeds damaged, but not actually destroyed, by burning. These would be more likely to germinate quickly and hence lead to an underestimate of the effect of burning at the first assessment date, prior to sowing wheat. The most important assessment was the weed populations within the actual wheat crop, and a reduction of 89–90% is very impressive. This effect may well not be so apparent in fields with natural black-grass populations because of the confounding effect of old seeds within the soil profile. Overall, the results were entirely consistent, and comparable, with those obtained with uncontrolled in-field straw burning in previous studies and vindicate the experimental approach used in this trial.

Condition and position of seed on the stubble appears to influence the extent to which burning alone can reduce *A. myosuroides* populations. As expected, control was reduced where seed had been lying on the soil surface for eight days, more closely mimicking realistic practical conditions, compared to where seeds were applied on the day of burning. This was on stubble with a small amount of trash left after baling on which only brief showers of rain had fallen.

It will be useful to explore the burner efficacy further in a range of stubble/trash situations to assess if it is a robust approach to weed control where straw has been chopped, when there are longer periods between seed shedding and burning, under different weather conditions at burning and against other grass-weeds, such as *Bromus* spp., *Avena* spp. and *Lolium multiflorum* (Italian rye-grass). The trial was undertaken on dry stubble and so it will be particularly important to show that the burner can also be used to reduce subsequent weed populations when there are higher levels of soil moisture.

While the burner prototype was adequate to show the potential of this equipment some modifications will be needed before it can be tested on a field scale to assess work rate and the economics of controlled burning as a weed control operation. Inconsistent burning proved a problem during the field trial so a way of increasing air flow to the burners will be needed when the machine is scaled-up. Most importantly, the design must incorporate a system to contain the burn within the burner housing and safe working practices must be developed to prevent a wild-fire across a stubble down-wind of where it is operated.

Acknowledgements

We thank Andrew Hughes for technical assistance with trials at Fenswood Farm, Long Ashton, North Somerset. We are very grateful to Calor Gas Ltd for funding this research.

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