The hidden costs of sulphonylurea herbicide use on micronutrient-poor soils

Peter O'Keeffe and Nigel Wilhelm

South Australian Department of Primary Industries, P.O. Box 1783, Port Lincoln, SA 5606

Summary. A series of field experiments was conducted on the Eyre Peninsula to examine the effects of herbicides on the nutrition of treated crops. Experiments investigating the effect of metsulfuron-methyl and chlorsulfuron on crop performance are reported here. The parameters measured were shoot growth, tissue nutrient concentration and grain yield. Application of metsulfuron-methyl to manganese-deficient barley and chlorsulfuron to zinc-deficient wheat crops caused yield penalties by intensifying the respective deficiencies. Yields were not affected when the herbicides were applied to plots which were trace element adequate. The consequences are that if adequate fertiliser regimes are not employed in the field, yield benefits due to weed control may be eroded by losses due to aggravated micronutrient deficiencies.

Introduction

In recent times there have been numerous anecdotal reports of herbicides impairing crop performance by what appeared to be induced nutritional stress. The fact that the vast majority of broad-acre crops are treated with at least one herbicide application during the season, coupled with evidence that large areas of these crops are grown under nutritional stress has prompted a number of studies into such interactions. Robson and Snowball (5) reported that chlorsulfuron could limit the ability of a crop to exploit available zinc and copper and that this effect could be particularly damaging if soil nutrient levels were marginal to low. These studies were carried out on acid soils and it was suspected that damage could be more severe on the highly alkaline soils common in South Australia (where herbicides such as the sulphonylureas are more active and persist in the soil for long periods (6)). The results presented here are of three experiments from a total programme of 46 conducted on the Eyre Peninsula over the last three years -they are indicative of results generally obtained.

Methods

Three sites were chosen in 1991 where previous plant and/or soil nutrient tests suggested that either zinc or manganese were inadequate for crop production. When selecting sites preference was also given to areas where paddock management prior to the forthcoming season would ensure that weed numbers were low. However, blanket applications of unrelated herbicides were sometimes necessary to minimize weed competition. Such management was deemed necessary to avoid competition from weed burdens confounding the effects of herbicides on crop nutrition.

The experiments were designed with complete factorial combinations of multiple rates of a single herbicide and of a particular nutrient. High basal rates of all other nutrients were used in an attempt to ensure that only the target element was limiting. Herbicide applications ranged from nil to 1.5 times recommended label rates.

The Farm Beach experiment (manganese-responsive) was sown to barley, Hordeum vulgare cv. Galleon at 50 kg/ha. The Butler and Moody experiments (zinc responsive and nutrient adequate, respectively) were sown to wheat, Triticum aestivum cv. Machete at 65 kg/ha. Plots were 20 m x 8 rows and treatments were replicated four times. Selected details for each site are presented in Table 1.

Plots were sampled for dry matter production of shoots and nutrient concentrations in youngest emerged blades (YEBs) at early tillering. Nutrient concentrations were determined by inductively coupled plasma spectrophotometry. Although only results for the "target" nutrient are reported here the concentrations of the following elements were also recorded: iron, manganese, boron, copper, zinc, calcium, magnesium, sodium, potassium, phosphorus and sulphur. Grain yields were assessed at harvest. Butler was also sampled for the presence of root pathogens mid-season because of interest in the link between herbicide application and increased disease severity (3).

Table 1. Selected characteristics for three experimental sites

	Farm Beach	Butler	Moody
Average annual rainfall	460 mm	375 mm	375 mm
Herbicide tested	metsulfuron-methyl	chlorsulfuron	chlorsulfuron
Timing of application	3 to 4 leaf stage	Pre-sowing	Pre-sowing
Surface pH[a] (1:5 H_20)	8.4	8.3	6.5
Surface texture[a]	Sandy loam	Sandy clay loam	Loamy sand
DTPA (2) extract. zinc[a] (mg/kg)	0.60	0.20	0.14
DTPA (2) extract. manganese[a] (mg/kg)	2.80	2.20	1.80
Soil carbonate[a] (%)	66.2	3.0	0.80

[a] Soil sampled to a depth of 10 cm from the surface

Results

Farm Beach (metsulfuron-methyl and manganese-deficient barley)

The application of metsulfuron-methyl depressed manganese concentrations in barley (Table 2). Although concentrations at early tillering were well above the critical level of I 1 mg/kg (I) tissue concentrations subsequently decreased and were deficient by early flowering (data not presented). The manganese-deficient nature of this site is obvious in the benefits to grain yield of increasing manganese applications (Table 2).

Table 2. Tissue nutrient concentrations at early tillering and grain yield at Farm Beach

Even the highest rate of manganese failed to completely overcome manganese deficiency. Plots treated with the recommended rate of 3.6 g/ha of metsulfuron-methyl yielded 17 % (600 kg/ha) lower than control plots, regardless of manganese treatment.

Butler (chlorsulfuron and zinc-deficient wheat)

Pre-sowing chlorsulfuron applications intensified zinc deficiency. Tissue zinc concentrations were depressed to well below the critical level of 17 mg/kg (7) by application of the recommended rate of 15 g/ha. This caused severe foliar symptoms, stunting and ultimately, reduced yields (Table 3). A low weed burden at this site caused the mean yield of nil chlorsulfuron plots to be lower than those of the 7.5 g/ha treatments.

Plots were sampled for the incidence of take-all (caused by *Gaeumannomyces graminis* var *tritici),* rhizoctonia bare patch *(Rhizoctonia solani)* and cereal cyst nematode *(Heterodera avenae)* but levels were found to be low and unrelated to herbicide or nutrient treatments (data not presented).

	YEB[a] manganese concentration (mg/kg DW)						Grain yield (t/ha)					
metsulfuron -methyl (g/ha)	Manganese (kg/ha)						Manganese (kg/ha)					
	0	1	3	7	12	mean	0	1	3	7	12	mean
0	18	22	28	41	56	33	3.0	3.3	3.6	3.9	4.1	3.6
1.8	16	19	24	32	43	27	2.9	3.3	3.3	3.6	3.6	3.3
3.6	15	18	21	28	39	24	2.2	2.5	3.1	3.3	3.6	3.0
5.4	14	16	20	29	37	23	2.1	2.4	2.6	2.9	3.3	2.7
mean	16	19	23	32	44		2.6	2.9	3.1	3.4	3.6	
	l.s.d.(P=0.05) Me=1, Mn=1 interaction=4						l.s.d.(P=0.05) Me=0.2, Mn=0.2 interaction,n					

[a] Youngest emerged blade

Table 3. Tissue nutrient concentrations at early tillering and grain yield at Butler

	YEB zinc concentration (mg/kg DW)						Grain yield (t/ha)					
chlorsulfuron (g/ha)	Zinc (kg/ha)						Zinc (kg/ha)					
	0	0.5	1.0	2.0	4.0	mean	0	0.5	1.0	2.0	4.0	mean
0	15	16	15	19	18	16	3.6	3.7	4.1	4.2	4.0	3.9
7.5	13	11	14	15	15	13	3.6	4.0	4.3	4.2	4.3	4.1
15	14	12	12	12	15	13	3.5	3.9	3.8	4.1	3.9	3.8
22.5	10	10	12	14	10	11	3.1	3.5	3.6	3.9	3.8	3.6
mean	13	12	13	14	15		3.5	3.8	4.0	4.1	4.0	
	l.s.d.(P=0.05) Ch=2, Zn=2 interaction=ns						l.s.d.(P=0.05) Ch=0.2, Zn=0.2 interaction ns					

Moody (chlorsulfuron and zinc-adequate wheat)

At Moody pre-sowing applications of chlorsulfuron reduced tissue zinc concentrations but yields were not decreased because tissue levels were still adequate for growth (Table 4).

Table 4. Tissue nutrient concentrations at early tillering and grain yield at Moody

chlorsulfuron (g/ha)	YEB zinc concentration (mg/kg DW) Zinc (kg/ha) 0	1.0	2.0	4.0	mean	Grain yield (t/ha) Zinc (kg/ha) 0	1.0	2.0	4.0	mean
0	26	28	33	36	31	4.4	4.5	4.4	4.1	4.4
10	18	24	24	34	25	4.8	4.4	4.4	4.3	4.5
15	19	24	21	29	23	4.5	4.0	4.6	4.4	4.4
mean	21	25	26	33		4.5	4.3	4.5	4.3	
	l.s.d.(P=0.05) Ch 2, Zn 3 interaction ns					l.s.d.(P=0.05) Ch=ns, Zn=ns interaction ns				

Discussion

Application rates of metsulfuron-methyl and chlorsulfuron which are in common usage in broad-acre farming in southern Australia caused grain yield losses in cereal crops which were growing on trace element-deficient soils. The cause of the yield depression was increased severity of the trace element deficiency. Yield penalties were sufficiently severe that benefits due to weed control would have been largely or even completely negated. However, if the crop is well nourished (as was the case at Moody) depressions in tissue concentrations of trace elements caused by the herbicide were transient, did not reach deficient levels and grain yield was not impaired.

The likely cause of this effect is depressed root growth and function. Robson and Snowball (5) suggested that chlorsulfuron impaired the nutrition of treated plants by deleterious changes to root morphology and physiology. Pederson and co-workers (4) found that metsulfuron-methyl caused substantial reductions in the length of lateral roots of field-grown barley.

The problem is avoidable. A farmer who is diligent with soil and plant testing can effectively plan a fertilizer regime that will avoid trace element deficiencies and thus also the aforementioned problems associated with some herbicides. This means that the excellent weed control properties that these chemicals offer can be fully exploited. Alternatively, these problem chemicals should be avoided if trace elements are lacking.

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