Sulfonylurea herbicide and Zinc / Phosphorus fertiliser interactions in wheat in the Central West NSW cropping belt (2001 to 2003)

Ken Motley, Extension Agronomist, NSW Agriculture (Forbes) **David Harbison,** Research Agronomist, Hi Fert Fertilisers (Molong) **Bob Thompson,** District Agronomist, NSW Agriculture (West Wyalong) **Andrew Rice,** Agricultural Consultant, Ivey ATP (Parkes) **Karen Roberts,** Extension Agronomist, NSW Agriculture (Parkes)

Key Points

- Chlorsulfuron herbicide was found to reduce wheat yields at some sites.
- Phosphorus (P) responses were closely correlated with soil P levels.
- No significant responses to zinc (Zn) fertiliser were recorded.
- P and Zn nutrition was not found to interact with chlorsulfuron herbicide damage in wheat.

Background

Applications of sulfonylurea (SU) herbicides such as chlorsulfuron (eg Glean®) and metsulfuron (eg Ally®) are known to result in reduced grain yield when used on some wheat varieties in some seasons (Lockley and Littlewood, 2000, 2001, 2002; Mullen et. al. 2003). However, the positive effects of early weed control on grain yield from SU herbicides often compensates for any risk of crop damage and the cost effectiveness of these herbicides makes them a popular choice.

Some farm advisers in central west (CW) NSW have suggested that there is an interaction between crop damage caused by SU herbicides and crop nutrition, particularly zinc (Zn). It has been suggested, that the negative effects of SU herbicides on grain yield are exacerbated by zinc deficiency in wheat crops. Following on from this, it is claimed that the application of SU herbicides on wheat yields can induce Zn deficiencies.

Zn is important in the activity of a number of enzymes in plants and also in the production of hormones which control growth processes such as stem and root elongation and leaf expansion. It is also involved in the plants ability to use nitrogen (Weir et. al. 1983).

Factors affecting Zn availability to plants are well documented in the literature. Armour and Brennan (1999) summarise the factors reducing Zn availability as; high soil pH, high levels of available soil P, low total soil Zn status, prolonged water logging, climatic conditions that favour rapid plant growth or reduce root growth, low soil vesicular-arbusicular mycorrhizae (VAM) and some herbicides.

Different crop species and cultivars within species are know to vary widely in their tolerance of low plant available Zn (Weir et. al. 1983; Armour and Brennan 1999; Lockley and Littlewood, 2000, 2001, 2002). Corn, linseed, soybeans and navy beans are considered very sensitive to low available soil Zn, while sorghum and cotton are moderately sensitive. Sunflower and wheat are considered to be least affected by low available soil Zn.

The interaction between herbicides and Zn nutrition of wheat has been studied in a number of experiments in South Australia and Western Australia.

Glass house pot trials in Western Australia by Robson and Snowball (1989) demonstrated soil incorporated diclofop-methyl (eg Hoegrass®) could induce Zn deficiency in wheat. The soil used in these experiments was a virgin brown sandy soil with extremely low Zn levels of 0.05 ppm (DTPA). Using the same methodology and soil medium, Robson and Snowball (1990) reported chlorsulfuron applications induced symptoms of Zn deficiency and reduced plant dry matter. They concluded the losses in production were most likely the effect of depressed root function and that these herbicides could induce Zn deficiency where the supply of Zn for the crop is marginal. Pedersdon et. al. (1994) noted the changes to root morphology and reductions in the length of lateral roots of barley as a direct consequence of metsulfuron herbicide applications. These root impacts can inhibit the uptake of water and immobile nutrients such as Zn, thereby intensifying deficiencies, and reducing yields on soils deficient in trace elements.

Field trial work in South Australia by O'Keefe and Wilhelm (1993) studied the effects of SU herbicide on grain yield of wheat growing on a sandy clay loam soil (pH_{water} 8.3), deficient in trace elements. Grain yield was reduced when wheat was treated with chlorsulfuron, but the yield in plots with adequate trace element nutrition was not impaired. This effect was only observed in one experiment from a total program of 46 conducted on the Eyre Peninsula over three years.

Some agronomic advisers have used this information as a basis for management recommendations to farmers on the nutrition of their wheat crops. This has resulted in the increased use of Zn fertiliser products (i.e. seed treatments, fertilisers and foliar sprays) on wheat crops treated with SU herbicides. It is estimated that Zn starter fertilisers are applied at sowing to approximately 20% of the wheat crops in the Forbes district. However, the applicability of the SA and WA trials on which these Zn recommendations are based, has been questioned for CW NSW. It has been suggested that the information has come from glass house trials and on very sandy soils in WA and SA, and it is not relevant to CW NSW.

Other than anecdotal reports, no trial evidence exists in CW NSW indicating wheat responses to Zn fertiliser, even on the high pH clay soils. Nor has the interaction between Zn fertilisers and SU herbicides been established.

In response to these concerns, a series of trials were conducted across CW NSW in 2001, 2002 and 2003 to provide objective data on the potential for SU and Zn interactions in wheat.

Methods

A series of 15 wheat trials were sown across CW NSW in 2001, 2002 and 2003 (see Table 1 for details). Most of the trial sites were sown in conjunction with NSW Agriculture S4 wheat variety trials and the site selection did not take into account the likely Zn status of the soil.

Table 1. Trial site details

Year	200							2002				2003			
Location	Bogan Gate	Wirrin	Gunni Gap	Quandialla		Euabalon West	Condo	Parkes	Gunni Gap	Gunni Gap	Quand	Gunnin Gap	Parkes	Wirriny	Quandi
Cooperator	Herbe	Muffet	Hodge	Kelly	Fishpo	Doyle	ARAS	Northpa	Scott	Coom	Kelly	Hodge	Northpar	Muffet	Kelly
Previous Crop	Wheat	Field	Wheat	Pasture	Pasture	Pasture	Pasture	Wheat	Pastur	Wheat	Canola	Wheat	Wheat	Fallow	
Soil test results						•Estimate									
pH ($CaCl_2$)	6.7	55	4.6	5.1	5	6.0*	5.4	46	4.8	46	4.7	4.8	5.8	73	
P ppm (Colwell)	37	52	25	35	17	13*	13	39	24	25	35	33	45	33	
Organic C	1.17%	1.32%	1.52%	1.77%	1.17%	0.68%*	1.75%	2.06%	1	1.52%	1.95%	0.96%	1.67%	1.20%	
CEC meq/100g	34.8	12.3	9.1	19.3	10.3	11.4*	13.5	124	11.2	9.5	11.7	9.39	27.5	24.8	
Exc Ca	65.8%	70.6%	57.8%	52.3%	58.3%	69%*	60.9%	52.3%	62	59.2%	53.0%	51.1%	58.8%	74.6%	
Exc Mg	27.2%	15.7%	22.8%	38.3%	22.8%	16%*	21.8%	29.5%	19.9	18.9%	29.2%	31.1%	34.1%	16.1%	
Exc Al	0.0%	0.0%	2.6%	0.3%	0.8%	0%*	0.2%	1.6%	0.0%	1.5%	0.0%	1.8%	0.0%	0.0%	
Zn ppm (DTPA)	0.3B	0.62	0.51	0.35	0.73	na	1.32	0.77	0.64	0.38	0.78	0.46	0.84	0.56	
Fertiliser (kg/ha)															
N pre sow	25	Nil	25	Nil	Nil	Nil	Nil	0	0	0	0	0	0	0	0
N at sow	18	18	18	27	18	18	18	18	18	18	18	18	18	18	18
P	20	20	20	30	20	20	20	20	20	20	20	20	20	20	20
Zn	6.5	6.5	65	7.2	48	48	4.8	4	4	4	4	4	4	4	4
Sowing															
Date	2nd	3"	30*	16th	16th	26* June	13th	5th June	3rd	4*	3rd	4* July	12th July	8th July	
Rate (kg/ha)	50	50	50	75	50	50	50	45	45	45	50	60	45	60	60
Chlorsulfuron															
Date	19th	23rd	1"	20*	4th	26* June	1st	15th	19th	19th	20"'	7th	7th	7th	29th
Rate (g/ha)	20	20	20	30	20	20	20	20	20	20	20	20	20	20	20
Other herbicides				•											
Products	Trista Banve	Tristar Banvel	Trista Banve	Dual	Tristar	Lontrel MCPA	Tristar	Tristar	Tristar Banve	Tristar Banve	Dual	Tristar Tiprex	Tristar	Tristar 2,4-D	
Dry matter cuts															
Date	13th	Not	6th Sep	23th	21th	Not done	21st	17th Oct	11th	11th	10th	Not	20th Oct	27th Oct	30th Oct
Rainfall															
Jan		0'	0				2.5	33	0	2	0	17	21	26	
Feb		67	40.75				399	208	112	121	115	38	90	90	
Mar		29	23.5				38.2	8	11	12	14	11	15	14	
Apr		32	54				16.3	48	12	12.5	16	14	20	2	
May		7	14.25				27.3	39	37.5	49	35	3	3	8	
Jun		70	53				50	10	4	8	17	18	32	33	
Jul		44	55				28.6	9	8	10	19	51	50	33	
Aug		17.5	19				19.5	3	0	7	14	58	79	64	
Sep		43.5	34				42	47	45	43	63	9	3	15	
Oct		22	47				25.4	0	0	0	0	30	39	23	
Nov		33	34.5				466	5	0	1.5	14	29	26	0	
Dec		0	1				2.8	17	23	40	15	32	34	14	
Total in crop		204	222				192.8	108	94.5	117	148	169	206	176	
Total		**365**	**376**				**339.1**	**427**	**252.5**	**306**	**322**	**310**	**412**	**322**	

While a further 2 trials were also sown at Garema and Gunningbland in 2003, severe drought conditions resulted in these trials sites being abandoned.

Trial; treatments included:

- two wheat varieties (Janz and Wollaroi);
- application of two SU herbicide treatments (Nil chlorsulfuron and + chlorsulfuron); and
- two Zn fertiliser treatments (Nil Zn and + Zn).

All treatments were all sown with phosphorus (P) at 20 kg/ha (except at Quandialla in 2001 where 30 kg P/ha was sown). Two additional nil (P) fertiliser treatments with Nil chlorsulfuron and + chlorsulfuron were also included to investigate the P response on each site and it's interaction with chlorsulfuron. In 2002 and 2003, two additional high P treatments at 40 kg P/ha were included to provide improved information of the P responsiveness of the trials sites.

The trials were arranged in a randomised block design with 3 replicates.

Di-ammonium phosphate (DAP) (18N:20P:0Zn) was used as the starter fertiliser. DAP Zinc-Cote® (17N:19P:5Zn) was used for the + Zn treatments. Fertiliser treatments where balanced with urea to ensure even rates of nitrogen (N) and P were applied in the DAP and DAP Zinc-Cote® starter fertilisers. A basal application of N as urea was applied to the nil P fertiliser treatments at the same rate of N as the DAP treatments. Glean® (chlorsulfuron 750g/kg) was used as the chlorsulfuron product. Glean® was applied to the appropriate plots at the early post emergent stage as indicated by the dates in Table 1.

As required, other herbicides were applied across the trial sites to minimise weed effects (see Table 1 for details).

Dry matter cuts were taken mid season. Very dry conditions in 2002 and 2003 meant dry matter cuts on some sites were not taken. The dry matter cuts were done late in 2003 due to the very dry conditions that inhibited early growth. Plant tissue samples (youngest emerged blade) were analysed for a full range of nutrients to ensure other nutrients were not deficient, and to provide further information on the Zn and P status of the different treatments. Grain yield, protein, screenings and test weights were recorded.

The results were statistically analysed using analysis of variance and spatial analysis.

Results and Discussion

Chlorsulfuron effect (Table 2)

Chlorsulfuron significantly reduced mid season dry matter of Janz and Wollaroi at Bogan Gate, Gunning Gap and Tottenham in 2001. Only Wollaroi dry matter was significantly reduced at Quandialla with chlorsulfuron. The chlorsulfuron effect at these sites did not interact with Zn fertiliser (ie the addition of Zn fertiliser did not reduce the chlorsulfuron effect on mid season dry matter). No dry matter samples were taken at Wirrinya or Euabalong in 2001 due to late sowing and time constraints. Chlorsulfuron had no effect on mid season dry matter at any site in 2002 or 2003.

Chlorsulfuron significantly depressed grain yield of Janz at Gunning Gap, Tottenham and Euabalong in 2001, whilst an increase in grain yield was recorded at Wirrinya in 2001. The yield depression with chlorsulfuron at Gunning Gap and Tottenham in 2001 occurred despite adequate P and Zn being present in the plant tissue. No tissue tests were taken at Euabalong in 2001.

Chlorsulfuron had no effect on grain yield in 2002. Grain yield at Gunning Gap of both Janz and Wollaroi was significantly increased with chlorsulfuron applications in 2003. The grain yield increase at Wirrinya in 2001 and Gunning Gap in 2003 when treated with chlorsulfuron was due to weed effects, although this was a visual appraisal only. Very dry conditions at Gunning Gap in 2003 meant that grass weed control was very difficult, as attested by the need for 2 applications of Tristar®.

The chlorsulfuron effect in 2001 was generally larger on early dry matter production than grain yield. Depressed early dry matter due to chlorsulfuron did not always result in depressed grain yields as seen in Wollaroi at Quandialla.

The chlorsulfuron induced yield declines at Gunning Gap and Tottenham in 2001 were accompanied by significantly higher grain protein levels. In contrast, grain protein levels in Wollaroi were reduced with chlorsulfuron at Euabalong in 2001. Chlorsulfuron had no effect on grain protein in 2002 or 2003.

No chlorsulfuron effect was found on grain screenings or grain test weight in 2001. Grain screenings and weight was not measured in 2002 or 2003.

Trials at Wagga have shown that pre sowing (incorporated by sowing) applications of chlorsulfuron to be more damaging than post emergent (5-6 weeks post emergent) applications (Lockley and Littlewood, 2001, 2002). Chlorsulfuron was applied to most of the trials reported in this paper early post emergent, typically 3-4 weeks post sowing (2-3 weeks post emergent). Only the Gunning Gap and Euabalong West sites in 2001 had the chlorsulfuron applied pre-emergent. It is unlikely to be a coincident that these 2 sites showed the greatest level of grain yield declines as a result of chlorsulfuron.

Chlorsulfuron has also been shown to be more damaging in wet years than dry years (Lockley and Littlewood, 2000, 2001, 2002). The results presented in this paper show a similar trend. The only year that chlorsulfuron induced grain yield deficiencies was in 2001, which was the year that had the greatest amount of in crop rainfall (Table 1). No chlorsulfuron effects were found in the very dry years of 2002 and 2003.

Ideally the chlorsulfuron should have been applied pre emergent to all of these trials. This is the most common farmer practice and it would have maximised the potential for chlorsulfuron damage. The wide geographical spread of these trials and time constraints at sowing prevented this happening in all but 2 of these trials.

Table 2. The effect of chlorsulfuron (Glean®) on mid season dry matter and grain yield of wheat at 15 sites over 3 years in West NSW

Year	**2001**							**2002**				**2003**			
Location	Bogan Gate Herbert	Wirrinya	Gunning Gap Hodges	Quandialla	Tottenham	Euabalong	Condobolin	Parkes North	Gunning Gap Scott	Bogan Gate Coombs	Quandialla	Gunning Gap Hodges	Parkes	Wirrinya	Quandialla
Dry matter production															
Janz Nil Chlorsulfuron	100%		100%	100%	100%		100%	100%	100%	100%	100%		100%	100%	100%
+ Chlorsulfuron	76%-		70% -	91%	66%-		98%	120%	98%	91%	95%		88%	96%	93%
Wollaroi Nil Chlorsulfuron	131%		106%	107%	101%		118%	106%	94%	95%	99%		153%	121%	51%
+ Chlorsulfuron	97%-		57%-	87%-	69% -		120%	127%	95%	90%	108%		132%	109%	44%
Janz DM at 100% (t/ha)	2.53		1.95	3.29	1.87		1.73	264	228	2.09	5.33		2.59	8 24	5.96
LSD (5%)	19%		24%	10%	21%		20%	33%	16%	10%	19%		34%	17%	18%
Grain Yield															
Janz Nil Chlorsulfuron	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
+ Chlorsulfuron	97%	113% +	94% -	105%	88%-	86% -	101%	113%	94%	93%	109%	121% +	100%	95%	106%
Wollaroi Nil Chlorsulfuron	104%	62%	83%	88%	85%	82%	87%	75%	72%	75%	74%	67%	42%	94%	39%
+ Chlorsulfuron	97%	61%	80%	87%	87%	77%	86%	71%	66%	66%	81%	94% +	56%	94%	39%
Janz Yield at 100% (t/ha)	2.32	2.76	2.59	5.70	4.04	1.88	1.94	0.92	1.58	0.44 Not	2.34	0.88	1.09	2.32	2.04
LSD (5%)	9%	12%	4%	6%	8%	8%	11%	17%	9%	analysed	22%	20%	16%	11%	8%

- significant decrease within variety +
significant increase within variety

Table 3. The effect of P fertiliser on grain yield of wheat at 15 sites over 3 years in Central West NSW

Year	**2001**							**2002**				**2003**			
Location	Bogan Gate Herbert	Wirrinya	Gunning Gap Hodges	Quandialla	Tottenham	Euabalong West Doyle	Condobolin	Parkes North	Gunning Gap Scott	Gunning Gap Coombs	Quandialla	Gunning Gap Hodges	Parkes	Wirrinya	Quandialla
Grain Yield															
P rate 0	100%	100%	100% -	100%-	100%-	100% -	100% -	100% •	100% -	100%	100%-	100% -	100%	100%	100% -
Kg P/ha 20	105%	104%	116%	108%	168%	124%	136%	93%	118%	90%	121%	143%	93%	97%	119%
40								94%	124%	91%	116%	136%	87%	102%	122%
Janz Yield at 100% (t/ha)	2.17	2.83	2.16	5.38	2.26	1.41	1.43	1.05	1.31	0.47 Not	2.02	0.68	1.18	2 33	1.76
LSD (5%)	9%	11%	5%	6%	13%	10%	13%	13%	9%	analysed	22%	23%	13%	10%	8%
Colwell P	37	52	25	35	17	13	13	39	24	25	35	33	45	33	

- significant decrease compared to 20 kg P/ha

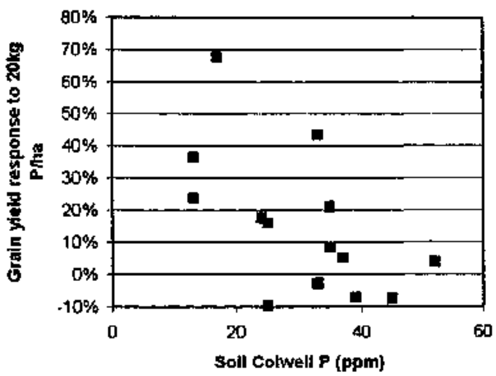
Phosphorus fertiliser effect

Significant yield responses to 20 kg/ha of P fertiliser were recorded at 9 out of the 15 sites over the 3 years of the trials (Table 3). The largest yield response to 20 kg P/ha was a 68% yield improvement at Tottenham in 2001. 40 kg P/ha did not give significant yield benefits over 20 kg P/ha at any of the sites in any year.

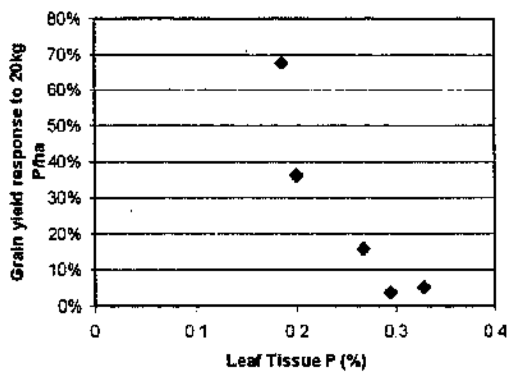
All of the significant P responses were recorded on sites with soil P (Colwell) levels of less than 35ppm (Graph 1). Yield responses to 20 kg P/ha were closely related to leaf tissue P levels in 2001 (Graph 2). Reuter and Robinson (1997) report critical wheat tissue P levels at Z 31 to be approximately 0.3%, which is strongly supported by these trials.

Chlorsulfuron did not significantly influence the level of P responsiveness at any of the P responsive sites. The level of P response was the same regardless of wether chlorsulfuron had been applied or not. Correspondingly, P fertiliser did not reduce the negative chlorsulfuron effects observed at Gunning Gap, Tottenham and Euabalong in 2001.

Graph 1. Soil Colwell P vs wheat grain yield response to 20 kg P/ha in 2001, 2002 and 2003



Graph 2. Leaf tissue P vs wheat yield response to 20 kg P/ha in 2001



Zinc fertiliser effect

A significant grain yield response to Zn fertiliser was recorded at the Quandialla site in 2002 in Janz when treated with chlorsulfuron. This result should be treated with caution as the response only occurred in Janz when treated with chlorsulfuron. Wollaroi showed no response to Zn fertiliser, with or without chlorsulfuron. The trial site had a very large coefficient of variation (CV) of 21% for grain yield, the largest out of all the sites over the 3 years. Grain yield data sets with CVs above 15% are generally thought to be unreliable due to large amounts of unexplained site variation. No Zn effect on mid season dry matter was recorded at this site and it also had one of the higher Zn soil test results (0.78 ppm DTP A), further adding confusion to the results obtained from this site.

No significant dry matter or grain yield responses to Zn fertiliser (with or without chlorsulfuron) were recorded at any others sites. This is despite soil Zn levels at 10 of the 15 sites being below the indicative critical level of 0.8 ppm (DTPA) set for wheat (Peverill et.al. 1999). Leaf tissue test results in 2001 showed Zn levels from 19.1 ppm (Wirrinya) to 34.6 ppm (Tottenham), which indicates all tissue samples were above the critical limit of 14 ppm at late tillering (Reuter and Robinson, 1997). The critical level of Zn in plant tissue, especially wheat, changes with the stage of growth. There is therefore no simple relationship between grain yield and tissue Zn (Conyers pers.com. 2002).

The evidence supporting Zn responses in wheat appears isolated to anecdotal evidence and unpublished trial results. Part of this hearsay and anecdotal evidence is that wheat maybe more responsive to Zn following canola, due to a reduction in VAM numbers. The importance of VAM for helping Zn uptake in crops such as sorghum and maize is well known. The Quandialla site in 2001 was the only site to follow canola out of these series of trials. However, the importance of VAM for Zn uptake in wheat and its interactions with canola are not well published and only speculation exists.

There is no single reliable soil test for Zn in Australia, although the DTPA test is the most widely used method in Australia (Armour and Brennan, 1999). The Zn / chlorsulfuron interactions demonstrated in pot trials by Robson and Snowball (1989, 1990) and in field trial by O'Keefe and Wilhelm (1993) was with soils that had zinc levels of 0.05 ppm and 0.20 ppm respectively (DTPA extractable zinc) and were proven to be Zn responsive. By comparison, none of the trial sites in this trial series within CW NSW may be considered deficient enough to respond to Zn and exhibit interactions with chlorsulfuron.

Wheat variety effects

The reported sensitivity of the durum wheats to SU herbicides or Zn deficiency (Mullen, et. al., 2003; McRae, et. al., 2004) was not observed in these trials. This further supports the earlier suggestion that these sites had adequate plant available zinc. Both Janz and Wollaroi appeared to be similar in response to P fertiliser and chlorsulfuron.

The main difference between the two varieties was that Janz yielded on average 20% higher than Wollaroi. This yield penalty is larger than has occurred in long term trials across NSW where the yield of Wollaroi has averaged out 7%-13% lower than Janz (Powell, 2000). The very low yields achieved at some sites with Wollaroi compared to Janz may be partially attributed to the root disease, crown rot. Wollaroi is well known to be very sensitive to crown rot, which can be a major problem in dry years such as 2002 and 2003. Severe crown rot was identified in some of the trials.

Testing of wheat varieties for sensitivity to SU herbicides at Wagga has never shown benefits from using Zn coated seed on any wheat variety (Lockley and Littlewood, 2001, 2002) both with and without SU herbicide applications.

Conclusion

These trials confirm the potential risk that chlorsulfuron may reduce wheat yields in some instances. However, these trials also demonstrate that chlorsulfuron does not always have a negative effect on wheat yields. Grain yield reductions only occurred in 3 of the 15 sites over the three years. Pre-emergent applications and wet winters appear to increase the potential for chlorsulfuron damage in wheat. The addition of Zn or P fertiliser did not reduce the yield penalty associated with chlorsulfuron. Claims that increasing Zn or P fertiliser rates will reduce the yield losses incurred by chlorsulfuron damage are unsubstantiated on the soil types typical of CW NSW.

The SU damage typically observed in wheat crops in CW NSW is most likely due to chemical effects, rather than any induced nutritional effects. These trials also highlighted that SU effects on early dry matter production do not always result in reduced grain yields.

The potential for Zn responses on soils with a $pH_{(CaCl2)} < 7$ in CW NSW is low. Based on these trials, the suggested critical Zn soil level of 0.8 ppm (DTPA) (Peverill et. al. 1999) does not appear to be applicable to soils with $pH_{(CaCl2)} < 7$ for identifying soils responsive to Zn applications. There appears to be no calibrated critical values of soil zinc for wheat on soils with $pH_{(CaC12)} < 7$ that have been shown to be applicable to CW NSW. These trials and others indicate that critical values are likely to be lower than 0.3 ppm (DTPA) or that the DTPA test is unreliable in acid soils. It is postulated that Zn responses are most likely to be found on highly alkaline soils with a $pH_{(CaCl2)} > 7.5$. Local experience suggests that even this may be an unreliable indication for potential Zn responses.

These trials raise the question as to why so many farmers in CW NSW are using Zn fertiliser when the potential for yield responses appear negligible. It could be that some advisers and farmers are over reacting to the possibility of Zn deficiency based on early season SU damage or other transient symptoms of ill thrift. Much trial evidence exists to show that wheat crops will often grow out of this early season damage and that farmers would be better rewarded by focusing on improving the N and P nutrition in wheat than Zn fertilisers.

Zn starter fertiliser such as DAP Zinc-Cote® (17N:19P:5Zn) contain slightly less P than ordinary DAP (18N:20P:0Zn). The concern is that farmers may use Zn starter products such DAP Zinc-Cote at ordinary DAP rates. This will result in a lower application rate of P, the most critical element in most wheat farming systems in CW NSW. This problem can easily be overcome by ensuring that Zn starter fertiliser rates are adjusted upwards to ensure the correct P rate is applied.

The other side of the argument is that Zn starter fertilisers are a relatively cheap (typically \$2.60/kg Zn) way of managing a deficiency that can be unpredictable and variable within a paddock. Exponents of Zn fertiliser use in CW NSW are also suggesting it is good agronomy to commence replacement of zinc removed in the grain before possible subclinical Zn deficiency begins to occur and production losses become significant.

Ideally these trials should be run over further years, with the hope of having wet years, to maximise the potential for chlorsulfuron damage. However, other higher research priorities will mean these trials will not be continued.

Acknowledgments

Thanks go to trial cooperators for hosting the trials. Greg Gibson, Tim McNee and Sharon Taylor provided technical assistance. John Francis supervised the trials in the Condobolin district in 2001. Arthur Gilmore, Sharon Taylor, Helen Nicole and Chris Dyson carried out statistical analysis of the trial data. Catherine Evans (CWFS) for critical comments on drafts of this report.

The Central West Farming Systems Group, Grain Growers Association, Hi Fert Fertilisers and GRDC funded these trials.

References

Armour, J.D. and Brennan, R.F. (1999). Zinc. In "Soil Analysis: an Interpretation Manual". Ed. K.I. Peverill, L.A. Sparrow, and D.J. Reuter. CSIRO Publishing Collingwood.

Lockley, P. and Littlewood, W. (2000). 2000 Results Cultivar X Herbicide Screening Wagga Wagga. NSW Agriculture.

Lockley, P and Littlewood, W. (2001). 2001 Results Cultivar X Herbicide Screening Wagga Wagga. NSW Agriculture.

Lockley, P and Littlewood, W. (2002). 2002 Results Cultivar X Herbicide Screening Wagga Wagga. NSW Agriculture.

McRae, F.J., McCaffery, D.W. and Carpenter, D.J. (2004). Winter Crop Variety Sowing Guide 2004. NSW Agriculture.

Motley, K., Harbison, D. and Rice, A. (2001). Canola and wheat responses to phosphorus in the Forbes District 2000. Winter Crop Agronomy Forbes Trial results. NSW Agriculture.

Mullen, C.L., Francis, R.J., Dellow, J.J. and McRae, F.J. (2003). Weed Control in Winter Crops 2003. NSW Agriculture.

O'Keefe, P. and Wilhelm, N. (1993). The hidden costs of sulphonylurea herbicide on micronutrient-poor soils. Proc. 7th Aust. Agron. Conf. Adelaide, S.A.

Pederson, R.N., Black, ID., Dyson, C.D and Hannam, R.J.(1994). Effects of the herbicide metsulfuron-methyl on root length, nutrient levels, grain protein, and yield of barley. Aust. J. Exp. Agric. 34, 499-504

Peverill, K.I., Sparrow, L.A. and Reuter, D.J. (1999). Soil Analysis: an interpretation manual. CSIRO. Australia.

Powell, C. (2000). Winter Crop Variety Experiments 1999. NSW Agriculture.

Reuter, D.J. and Robinson, J.B. (1997). Plant analysis: an interpretation manual. CSIRO. Australia.

Robson, A.D. and Snowball, K. (1989). The effect of 2-(4-2',4'-Dichlorophenoxy-phenoxyl)-methyl propanoate on the Uptake and Utilization of Zinc by Wheat. Aust. J. Agric. Res. 40, 981-90.

Robson, A.D. and Snowball, K. (1990). The effect of chlorsulfuron on the uptake and utilization of copper and zinc in wheat. Aust. J. Agric. Res. 41, 19-27.

Weir, R.G., Holland, J.F. and Doyle A.D. (1983). Zinc deficiency and its treatment in northern NSW. Agdex 102/531. NSW Agriculture.