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TO THE

POTASH-PHOSPHATE INSTITUTE

R. J. Goos, Associate Professor of Soil Science, Project Leader
B. E. Johnson, Instructor of Soil Science
F. J. Sobolik, Area Soils Agent
B. M. Holmes, Graduate Research Assistant

With assistance from:

Carrington, Minot, and Williston Experiment Stations
R. Stack, Professor of Plant Pathology
R. Hosford, Professor of Plant Pathology
M. Sweeney, Associate Professor of Soil Science

Program Orientation

Field experiments were established in with 3 experimental designs: I. Imazalil-KCl studies, where the effects of both KCl fertilization and the fungicide Imazalil on common root rot (CRR) of barley were studied. II. Imazalil-MAP studies, where the effect of Imazalil placement (seed vs. fertilizer placement) on stand and CRR of barley was studied. III. KCl-foliar disease studies, where the effect of KCl rate on foliar disease severity of zero-tilled winter wheat was studied. The most complete information, at this writing, was associated with part I. Greenhouse experiments on N-form and chloride effects on tanspot were performed as well.

I. KCl-Imazalil studies.

A factorial combination of three KCl rates (0, 50, 200 kg KCl/ha) by 2 Imazalil seed treatment rates (0 and 0.1 g active ingredient/kg seed at a seeding rate of 75 kg/ha). The variety was Morex. Experimental design was a randomized complete block with 4 replicates at Minot, 5 at Stanley and Williston recrop, and 6 at the other 3 sites. All sites were completed through harvest. Whole culms at boot stage were analyzed for water-extractable nitrate and chloride by steam distillation and $AgNO_3$ titration, respectively. Common root rot by the 1-4 rating scale was determined on 24 subcrown internodes per plot. Plots were harvested by plot combine. Selected soil properties are shown in Table 1.

KCl fertilization dramatically increased plant Cl levels, as expected (Table 2). Tissue chloride levels without KCl fertilization (2.6-16.8 g Cl/kg) were somewhat higher than observed in previous studies even though soil test Cl levels were quite low at some sites. In general, basal Cl levels in the plant were directly related to soil Cl levels, with the exception of Williston fallow. It seems possible that the soil samples were chloride-contaminated at that site. Post-harvest samples from this site show almost no chloride. The Carrington site had considerable Cl in the subsoil, presumably due to the history of KCl fertilization and manuring. Plant chloride levels were increased at Carrington, but certainly not to the same degree as at the other sites. Does the chloride data at Carrington suggest a maximum Cl accumulation figure of around 22 g/kg for barley? Imazalil significantly increased chloride concentrations at Underwood, but the reason for this response is not known.

Nitrate concentrations were decreased significantly by KCl fertilization at all sites, including Carrington (Table 3). The reason for this response is still not known. Three possibilities exist: 1) chloride interferes with nitrate uptake, 2) chloride interferes with nitrification, 3) chloride stimulates photosynthesis, growth, and nitrate reduction by plant tissues. <u>This issue needs to be resolved!</u> It has been inferred that chloride-nitrate interactions may be responsible for the effect of KCl on CRR. But direct cause-and-effect evidence is still lacking.

The effect of KCl on nitrate accumulation at Carrington is noteworthy, as a nutritional response to Cl is not likely. This suggests that position of the chloride in the profile rather than total amount of chloride is important for chloride to influence plant nitrate. That is, even though this site had abundant subsoil chloride, chloride fertilization still reduced nitrate accumulation, which implies that the chloride must be in the same zone as nitrification or nitrate uptake. This is important, because if the nitrate-chloride explanation for KCl effects on CRR is vindicated in subsequent research, then the position of residual chloride would have to be considered in chloride management.

Effects of either KCl or Imazalil on CRR were observed at 4 of 6 sites (Table 4). No effect of either KCl or Imazalil was noted at Underwood or Williston fallow. Imazalil alone reduced CRR at two sites, Carrington and Minot. The effect at Carrington was highly significant, while at Minot the effect was only marginally significant.

Effects of both KCl and Imazalil on CRR were observed at two sites - Stanley and Williston recrop. These two sites give us differing information on the interaction of KCl and Imazalil on CRR. At Stanley, KCl fertilization without Imazalil decreased CRR about 0.5 unit. However, Imazalil dramatically reduced CRR and eliminated any effect of KCl. A different response was obtained at the Williston recrop site. The effects of KCl and Imazalil were additive rather than exclusive. That is, both KCl and Imazalil reduced CRR and their effects complemented each other. Two theories may explain the difference in KCl-Imazalil interaction at these two sites: 1) since overall disease levels were higher at the Williston recrop location, there was more potential for both KCl and Imazalil to decrease disease and 2) Imazalil was unusually effective at reducing CRR at the Stanley location, reducing CRR from moderate (3.0) to just above slight (2.3) severity. Once Imazalil had reduced CRR to slight levels there was less potential for a KCl effect.

These experiments suggest that KCl fertilization should not be considered a "substitute" for effective and economical fungicides, but rather as a technology which can be used in conjunction with fungicides, especially under severe disease pressure. For example, a re-examination of Table 4 shows that the lowest CRR reading at each site (except Underwood) was associated with treatments receiving both KCl and Imazalil.

Significant treatment effects on grain yield were observed in 5 of 6 trials. Imazalil increased grain yield an average of 5 bu/A at Carrington. This site had been in continuous barley for over 10 years and cultures of the subcrown internodes indicated some take-all infection, a more destructive disease than CRR. Yield variability was also highest at this site, presumably due to spotty infestations of barley thrip, aphid, and spot blotch.

Yields were increased by 4-8 bu/A by KCl fertilization at Underwood. This response may have been a nutritional response to chloride, as the soil chloride test was quite low (Table 1). However, this site had a considerable infestation with spot blotch, and reduction of this disease may also have been responsible for the KCl response. Tissue analyses for K not complete at this writing.

Yields were reduced an average of 5 bu/A by Imazalil at Minot. Imazalil has potential phytotoxic side effects on barley (seedling toxicity, alteration of tillering patterns, delay of maturity, etc.), but it is not known which of these effects would be responsible.

Yields were increased an average of 2 bu/A by Imazalil treatment and 3-4 bu/A by KCl at the Stanley site, generally following the trends found in CRR reduction. This site had an amazing yield level for barley on non-fallowed land in western ND.

Yields tended to be about 2 bu/A higher at the Williston fallow site with KCl fertilization. Since CRR was not influenced by treatment at this site, and since foliar diseases were not appreciable, this response was either a K or Cl response or a data anomaly. KCl did visibly advance maturity at this site, and perhaps a maturity/environmental interaction was responsible. Yields were not influenced by treatment at the Williston recrop site.

Conclusion

Much yet needs to be learned with regards to chloride fertilization and small grain production in North Dakota. One major limitation is the inability of field research to measure small (0-3 bu/A) yield responses precisely. This is particularly important in research such as this where very inexpensive treatments are used (Imazalil costs around 50¢/Acre and 50 kg KCl/ha would cost around $2.00/Acre). The yield responses needed to pay for these treatments are less than our detection ability in field research.

Another critical research need is to actually understand why KCl fertilization reduces CRR, and if there are indeed two completely different types of crop responses to chloride (a direct nutritional response vs. an indirect response due to disease suppression). Gaining unequivocal data will be difficult.

II. Imazalil-MAP studies.

This experiment was a factorial combination of three Imazalil rates (0, 0.1, and 0.3 g/kg) placed two ways (on the seed vs. on drill-applied MAP). The reason for this experiment was to see if the phytotoxicity of Imazalil could be reduced by fertilizer rather than by seed impregnation. Since Imazalil does not disinfest the seed (like Vitavax), placement of the Imazalil on the seed is not mandatory.

The effect of treatment on relative stand counts is shown in Table 6. Seed-applied Imazalil did reduce germination, as has been shown before. Placing the Imazalil on the MAP eliminated all seedling damage. However, placing the Imazalil on the MAP also eliminated all effect on CRR (Table 7). Thus, fertilizer-placement of Imazalil can not be recommended. It is not known why there was absolutely no effect of Imazalil-impregnated MAP on CRR, even at 3 times the labelled rate. Perhaps there was a chemical interaction between the phosphate and the fungicide. Such interactions have been shown to exist for liquid fertilizers and herbicides, but pesticide compatability with dry fertilizers has not been studied. This is important since the amount of pesticide-impregnated dry fertilizer increases each year.

III. KCl-winter wheat studies.

Since these studies are being conducted by a graduate student, Barb Holmes, the plant and soil analyses are not complete at this writing, so only a summary will be given. Experimental design was simply 5 KCl rates (0, 25, 50, 100, and 200 lb K_2O/A) topdressed to zero-tilled winter wheat.

Disease pressure was very severe this year. Instead of tanspot being our predominant disease, as is usual, we had a severe progression of disease which included tanspot, leaf rust, *Septoria*, bacterial diseases, and scab. Thus, disease ratings were very difficult, as assignment of disease damage to specific organisms is difficult when there are several pathogens on the leaf.

Chloride levels in the soil are given in Table 8. The sites were amongst the lowest ever sampled in North Dakota. Some sites had negligible chloride (titration values equal to the blank).

Plant disease ratings are summarized in Table 9. Foliar diseases (leaf spot plus leaf rust) was reduced at New Rockford and Buffalo. Combined leaf diseases tended to be reduced at Cuba, but the tanspot portion was definitely reduced. Diseases were not reduced at the other sites. Grain yields were not increased (Table 10), but yields were poor due to late-season stress, severe late-season disease pressure, and grasshopper predation at some sites.

IV. Greenhouse studies

Three greenhouse studies were performed to evaluate the interaction of N-form and chloride on tanspot. Much data has been collected, but the story can be summarized in Table 11. N form predominates the data. Going from KNO_3 to (Urea + N Serve) causes a dramatic drop in disease. Chloride has no effect on disease with (Urea + N-Serve), but chloride only reduced disease at the high rate with KNO_3 nutrition. This supports my contention that the "chloride effect" on plant disease is probably an indirect nitrogen effect. The greenhouse data will be published very soon.

Table 1. Selected soil characteristics.

Site	Soil series	0-15 cm† pH	0-15 cm† P	0-15 cm† K	0-60 cm NO_3-N	0-60 cm Cl	60-120 cm Cl	Previous crop
			---------- kg/ha	----------	----------	----------		
Carrington	Emrick loam	7.7	76	1150	160	79	93	barley‡
Underwood	Bowbells loam	7.8	13	810	77	4	7	sunflowers
Minot	Williams loam	5.9	24	850	75	20	105	barley
Stanley	Roseglen loam	7.8	30	1360	130	2	16	wheat
Williston fallow	Max loam	6.4	36	580	260	63*	27*	fallow
Williston recrop	Max loam	6.6	31	500	75	12	33	wheat

†pH in water (1:1 mixture), P by Olsen method, K by ammonium acetate extraction.
‡Site had been in continuous barley for >10 years.
*See text.

Table 2. Effect of KCl and Imazalil on chloride content of barley culms at late boot stage, North Dakota, 1986.

KCl	Imazalil	Site: Carrington	Underwood	Minot	Stanley	Williston fallow	Williston recrop
kg/ha	g/kg	----------	----------	---------- g Cl/kg	----------	----------	----------
0	0	16.8	2.6	6.3	4.1	2.3	3.2
50	0	18.2	5.9	9.5	9.2	6.6	6.9
200	0	22.2	18.6	15.8	17.5	13.1	13.4
0	0.1	16.2	2.7	5.9	3.9	2.9	2.7
50	0.1	19.6	7.2	9.3	8.9	5.5	6.3
200	0.1	22.3	20.8	15.7	17.0	13.0	12.7
SE†		0.7	0.5	0.7	0.6	0.4	0.5
Significance of F (Pr>F)							
KCl		<.01	<.01	<0.01	<0.01	<0.01	<0.01
Imazalil		NS	<.01	NS	NS	NS	NS
KCl x Imazalil		NS	NS	NS	NS	NS	NS

†Standard error.

Table 3. Effect of KCl and Imazalil on nitrate content of barley culms at late boot stage, North Dakota, 1986.

KCl	Imazalil	Site: Carrington	Underwood	Minot	Stanley	Williston fallow	Williston recrop
kg/ha	g/kg	g N/kg					
0	0	4.4	3.9	3.2	3.6	3.7	1.5
50	0	4.4	2.4	3.2	3.5	3.2	1.4
200	0	3.9	1.8	2.2	2.5	2.3	1.0
0	0.1	5.0	3.5	3.5	3.8	3.4	2.0
50	0.1	4.6	2.6	3.0	3.5	3.3	1.5
200	0.1	4.0	2.7	2.5	2.8	2.6	1.0
SE†		0.2	0.4	0.2	0.3	0.2	0.1
Significance of F							
KCl		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Imazalil		NS‡	NS	NS	NS	NS	NS
KCl x Imazalil		NS	NS	NS	NS	NS	NS

†Standard error.

‡Not significant (Prob. > F greater than 0.20).

Table 4. Effect of Imazalil and KCl on CRR of barley, North Dakota, 1986.

KCl	Imazalil	Site: Carrington	Underwood	Minot	Stanley	Williston fallow	Williston recrop	Average
kg/ha	g/kg	CRR Index						
0	0	3.4	2.2	3.0	3.0	3.5	3.4	3.1
50	0	3.2	2.2	2.9	2.6	3.4	3.2	3.0
200	0	3.2	2.0	3.1	2.5	3.4	3.1	2.9
0	0.1	2.8	2.1	3.0	2.3	3.4	3.2	2.8
50	0.1	2.7	2.0	2.9	2.3	3.3	2.8	2.7
200	0.1	2.7	2.0	2.8	2.2	3.3	2.8	2.6
SE†		0.1	0.1	0.1	0.1	0.1	0.1	
Significance of F								
KCl		NS‡	NS	NS	0.06	NS	<0.01	
Imazalil		<0.01	NS	0.08	<0.01	NS	<0.01	
KCl x Imazalil		NS	NS	NS	0.17	NS	NS	

†Standard error.

‡Not significant (Prob. > F greater than 0.20).

Table 5. Effect of KCl and Imazalil on barley yields, North Dakota, 1986.

KCl rate	Imazalil rate	Site: Carrington	Underwood	Minot	Stanley	Williston fallow	Williston recrop	Average
kg/ha	g/kg	bu/A						
0	0	57.7	88.5	86.5	92.9	49.7	45.2	70.1
50	0	53.6	97.4	87.7	94.7	52.2	45.7	71.9
200	0	55.6	93.3	86.4	96.2	52.1	47.0	71.8
0	0.1	62.2	90.5	84.0	96.1	48.8	47.9	71.5
50	0.1	58.4	94.3	80.4	95.1	49.8	44.9	70.4
200	0.1	63.4	98.4	82.3	99.0	51.6	48.5	73.9
SE†		4.0	2.3	2.8	1.6	1.3	1.5	
Significance of F								
KCl		NS‡	0.01	NS	0.13	0.15	NS	
Imazalil		0.09	NS	0.06	0.11	NS	NS	
KCl x Imazalil		NS	NS	NS	NS	NS	NS	

†Standard error.

‡Not significant (Prob. > F greater than 0.20).

Table 6. Effect of Imazalil rate and placement on relative stand density of barley, North Dakota, 1986.

Imazalil rate	Placement	Site: Carrington	Underwood	Minot	Stanley	Williston fallow	Williston recrop	Average
g ai/kg		% stand†						
0	--	100	100	100	100	100	100	100
0.1	on seed	88	102	94	90	83	102	93
0.3		67	84	76	80	76	78	77
0.1	on MAP	88	104	103	96	112	104	101
0.3		96	104	108	96	102	98	101

MAP = Monoammonium phosphate (11-52-0)

†Stand count of plots receiving Imazalil relative to plots not receiving Imazalil.

Table 7. Effect of Imazalil rate and application method on CRR of barley, North Dakota, 1986.

Imazalil rate	Placement	Site: Carrington	Underwood	Minot	Stanley	Williston fallow	Williston recrop	Average
g/kg		CRR Index						
0	--	3.4	2.6	3.3	2.7	2.7	3.2	3.0
0.1	Seed	3.2	2.6	3.2	2.6	2.6	3.1	2.9
0.3		2.7	2.0	2.8	2.2	2.2	2.9	2.5
0.1	Fertilizer	3.4	2.4	3.3	2.7	2.7	3.2	3.0
0.3		3.4	2.7	3.3	2.7	2.7	3.1	3.0

Table 8. Chloride levels in the winter wheat sites.

Site	Chloride level 0-60 cm	60-120 cm
	------- kg Cl/ha ------	
New Rockford	1	1
Buffalo	28	140
Embden	3	10
Cuba	15	10
Bisbee	0	0
Rolette	0	0

Table 9. Combined disease ratings (all leaf diseases) as a function of KCl rate. North Dakota, 1986.

KCl rate	Site and leaf position New Rockford F-1	Buffalo F-1	Embden F-1	Cuba F	Cuba (tanspot only) F	Bisbee F	Rolette east F
lb K_2O/A	-------------	-------------	% leaf area		-------------		
0	7.5a	39a	4.0a	50a	38a	20a	8.5
25	4.3b	33ab	3.9a	33a	25b	20a	7.2
50	3.6b	37ab	3.2a	42a	32ab	15a	7.8
100	5.2b	28b	3.4a	40a	27b	16a	9.1
200	3.2b	31ab	3.3a	39a	24b	18a	5.9

F = Flag leaf.
F-1 = Leaf below Flag Leaf.

Table 10. Grain yields as influenced by KCl rate.

KCl rate	Site			
	New Rockford	Embden	Cuba	Bisbee
lb K_2O/A	bu/A			
0	13.8a	27.4a	19.3a	22.9a
25	14.7a	23.8a	16.4a	23.9a
50	13.9a	27.8a	17.0a	23.3a
100	18.3a	25.9a	23.1a	26.6a
200	15.6a	29.2a	23.0a	25.0a

Table 11. Effect of N-form and chloride on tan spot of wheat.

N source	N rate	Cl rate, mg/kg soil		
		0	50	100
	mg N/kg	% Tan spot, leaf F-1		
KNO_3	150	42	51	20
Urea + N-Serve†	150	10	14	10

†N-Serve applied at 20 mg/kg of active ingredient.