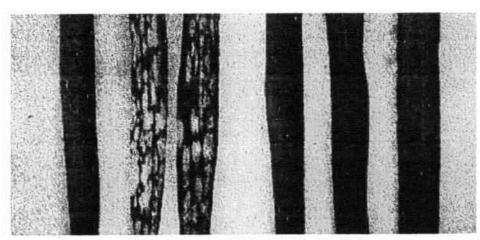
Physiological Leaf Spot and Chloride

Russ Karow and Dick Smiley

Physiologic leaf spot (PLS) is a malady of winter wheat that causes flag leaf spotting and destruction of lower plant leaves in severe cases. Yield losses from zero (when incidence is low) to as much as 10 percent (in severe cases; Smiley et al, 1993a) have been reported. PLS leaf lesions (oval to irregular shaped, chlorotic to necrotic spots) are similar to those associated with the fungal diseases tan spot and septoria, but no casual pathogen has ever been successfully isolated from PLS lesions. While foliar fungicides can be effective in treating tan spot and septoria, PLS seems unaffected by such fungicides (Smiley et al., 1993b; Engel et al., 1996). There is a substantial body of evidence that suggests PLS is not a disease, but if not, then what is the cause?

Some researchers now believe that PLS is caused by chloride deficiency - that it truly is a physiologic spotting. Chloride has been recognized as a plant nutrient since the mid-1950's (Engel, 1995). In a 1954 paper, Broyer et al described the typical symptoms of severe chloride deficiency - wilting followed by leaf chlorosis, necrosis and bronzing and branching and clubbing of lateral roots. However, it was believed that chlorine would rarely be deficient in plants "because of its high solubility and availability in soils and because it is also transported in dust or tiny moisture droplets by wind and rain to the leaves where absorption occurs (Salisbury, 1978)." Chloride is generally listed as a micro-nutrient in books such as the Western Fertilizer Guide. It is involved in photosynthesis and is an essential element in plants for this reason. It has also known to be involved in some plant turgor responses. Chloride has been implicated in a number of beneficial plant responses to disease and environmental stress, but it has been hard to show this definitively.

Some of the most definitive chloride-disease related work was done in western Oregon. Tom Jackson and Neil Christensen demonstrated that chloride fertilizers could reduce the affect of take-all in winter wheat in western Oregon. In his case, the chloride effect appears to be two-fold, affecting nitrogen-transforming bacteria and wheat plants themselves. In acidic soils, chloride reduces bacterial conversion of ammonia to nitrate nitrogen. By keeping nitrogen in the ammonic form and enhancing ammonium uptake by plants, the area immediately adjacent to plant roots is acidified and is unfavorable for the take-all organism. But wheat plants, per se, were also affected by chloride. Plants fertilized with ammonium chloride consistently produced higher yields, at similar take-all severity levels, than plants fertilized with other nitrogen materials. The chloride-fertilized plants apparently were able to better tolerate the disease (Christensen et al, 1990). The specific cause of this tolerance is not know.



Winter wheat flag, F-1, and F-2 leaves at heading without and with chloride (l to r). Photo by Richard Engel, Montana State Univ.

In the case of PLS, like earlier chloride work, the specific effect of the chloride on the wheat plant is not known, but data suggest that there is a definite beneficial response. Leaf spots of unknown origin have been observed in the Pacific Northwest for decades. The problem was thought to be variety specific and was often called genetic flecking. It was only an

---

Russ Karow is an extension agronomist with the Dept. of Crop and Soil Science at OSU. Dick Smiley is a plant pathologist at and superintendent of the Columbia Basin Agricultural Research Center.

EXT/CRS 108
January, 1997

occasional problem, but in the late 1980s, PLS was observed with greater frequency and severity in eastern Oregon and Washington. A number of growers asked that the "disease" be looked at more closely.

In 1990, Dick Smiley and co-workers at the Columbia Basin Ag Research Center initiated a set of trials to look at PLS in detail. They were interested in determining the effect of management practices – cultivars, planting dates, fungicides, herbicides and fertility. They found that cultivars varied significantly in susceptibility. Stephens, the most widely grown winter wheat in eastern Oregon, is also the most susceptible wheat. Table 1 is taken from a *Plant Disease* paper by Smiley et al (1993b). It gives mean PLS ratings for cultivars across six site-years. While most club wheats tend to have lower ratings, there is no pattern for red versus white wheats. Reds and whites of various origins are scattered through the ratings. The two triticales tested showed high levels of resistance. Increased soil-applied nitrogen fertility decreased the level of PLS. Delay in seeding reduced the level of PLS, but by the soft dough stage, only November seedings showed a significant reduction in PLS. Reducing the frequency of wheat in the cropping system tended to reduce PLS levels. Fungicides, tillage practices, herbicides and differential nitrogen timing had inconsistent or no effect on PLS. Perhaps the most interesting finding was that foliar applications of urea plus calcium chloride reduced PLS levels and gave significant grain yield increases.

Work with chloride was being done in Montana at this same time. Engel and co-workers evaluated 143 cultivar by site data sets from experiments conducted across south-central and northeast Montana between 1988 and 1994 (Engel, 1995). Granular potassium chloride was used as the chloride source in their studies. They reached the following conclusions:

1) Plants had adequate chloride nutrition when whole-plant chloride concentrations were greater than 0.40 percent at heading. Plants with heading chloride concentrations below 0.10 percent generally responded to chloride applications with an average 5.1 bushels per acre yield increase.

2) Soil test levels of 32 pounds per acre or more available chloride (top two feet) were required to achieve the 0.40 percent whole plant chloride concentration.

3) PLS was generally observed on susceptible cultivators when the plant chloride concentrations were below 0.10 percent and soil levels were below 10 pounds per acre, *but not always*.

They state "To date, our experience indicates that in susceptible varieties leaf spotting was favored by a combination of low soil chloride, plus prolonged wet and cool weather particularly during vegetative growth stages." Chloride applications were observed to increase kernel size in most situations and in some instances resulted in yield increases in the absence of leaf spotting.

Engel and co-workers did PLS-specific studies using granular potassium chloride at three Montana locations in 1993-95 (Engel et al., 1996). They found that variety susceptibility varied greatly. Kestrel, a hard red winter wheat developed by the University of Saskatchewan, was most susceptible. Stephens was included in their trials and was rated as only moderately susceptible. They noted that PLS symptoms appeared at flag leaf emergence, first on the oldest, then younger leaves. Leaf spot number and size increased up to the watery-ripe grain fill stage. Repeated fungicide applications had no affect on symptom development. The critical, at-heading, whole-plant-tissue concentration level was verified at the 0.1 percent. A two-foot soil plus fertilizer chloride level of at least 24 pounds per acre was "sufficient to effectively minimize leaf spot damage and improve grain yields." Two other interesting observations were made:

1) "The low chloride rates required suggest that foliar applications, particularly if made early during vegetative growth, may provide another approach for correcting potential leaf spot damage."

2) Leaf spots on a susceptible variety are a definite indication of chloride deficiency, but the absence of leaf spotting does not mean that plants are not chloride deficient. PLS resistant varieties responded to chloride applications when soil chloride levels were low.

Steve Reinertsen with McGregor Company in eastern Washington has also conducted a number of chloride fertilization trials over the past two years. In the summary of his 1996 data he states "It is now clear, when PLS is present, chloride applications tend to eliminate the symptoms. In all cases we tested where PLS symptoms occurred in check plots, chloride applications produced yield increases. It also appears, even when symptoms are not present, yield responses from chloride applications are possible, but not consistent. Also, varieties which do not express symptoms of PLS may still respond to chloride applications."

More chloride research is underway across the western United States. Oregon data thus far suggest that the effect of chloride on PLS is real (Table 2), but data also suggest there is a need to develop a better understanding of other environmental factors that contribute to PLS and to evaluate critical chloride levels under Oregon conditions. As a starting point, have adequate chloride in a cropping system to assure wheat plant tissue concentrations of at least 0.40% at heading or to have at least 32 lb/a chloride in the top two feet of soil. While attaining these levels is likely to reduce PLS symptoms, there is no guarantee that you will obtain a yield response.

We encourage you to set up valid "with and without" comparisons in fields if you choose to use chloride treatments, and we suggest that you have a chloride test run on your fall soil samples. Data on residual chloride levels across various rotations and soil types will be useful.

References

Broyer, T.C., A.B. Carlton, A.B. Johnson, and P.R. Stout. 1954. Chlorine: a micronutrient element for higher plants. Plant Physiol. 29:526-532.

Christensen, N.W., M.A. Brett, J.M. Hart, and D.M. Weller. 1990. Disease dynamics and yield of wheat as affected by take-all, N sources and fluorescent Pseudomonas. Transactions, 14th International Congress of Soil Science, Vol. III: 10-15, Kyoto, Japan, 12-18 Aug. 1990.

Engel, R. 1995. Chloride nutrition of western wheat. *In* Proceedings of the Western Nutrient Management Conference, Salt Lake City, Utah.

Engel, R.E., P.L. Bruckner, D.E. Mathre and S.K.Z. Brumfield. 1996. A chloride deficient leaf spot syndrome of wheat. Soil Science Society of America Journal: in press.

Reinertsen, S.A. and S.B. Wuest. 1995. 1995 Research Compendium. The McGregor Company, Colfax, WA.

Salisbury, F.B. and C.W. Ross. 1978. Plant Physiology, 2nd ed. Wadsworth Publishing, Belmont, CA.

Smiley, R.W., L.M. Gillespie-Sasse, W. Uddin, H.P. Collins and M.A. Stoltz. 1993a. Physiologic leaf spot of winter wheat. Plant Disease 77:521-527.

Smiley, R.W., W. UdDin, P.K. Zwer, D.J. Wysocki, D.A. Ball and T.G. Chastain. 1993b. Influence of crop management practices on physiologic leaf spot of winter wheat. Plant Disease 77:803-810.

Table 1. Leaf spot ratings[a] on winter wheat cultivars at five eastern Oregon locations.

Cultivar	Market class[b]	Mean
Buchanan	HR	1.3
Tres	CL	1.6
Dusty	SW	1.7
Moro	CL	1.9
Ute	HR	2.2
Hyak	CL	2.3
Cashup	SW	2.4
Andrews	HR	2.5
Rohde	CL	2.8
Wanser	HR	2.9
Daws	SW	3.0
Basin	SW	3.3
Hill 81	SW	3.4
Eltan	SW	3.5
Gene	SW	3.5
Oveson	SW	3.6
Yamhill	SW	3.7
Madsen	SW	3.9
Lewjain	SW	3.9
Malcolm	SW	3.9
Batum	HR	4.1
Kmor	SW	4.1
MacVicar	SW	4.1
Hoff	HR	4.1
Stephens	SW	5.3
LSD *(P=0.05)*		*0.9*

[a] Leaves are flag leaf (F) and first (F-1), second (F-2), third (F-3), and fourth (F-4) leaves below the flag leaf. Ratings are on a 0-10 scale, where 0=no symptoms, 1=<4 spots on the F-4 or F-3, 2=<25% necrosis on F-3, 3=>25% on F-3, 4=<25% on F-2, 5=>25% on F-2, 6=<25% on F-1, 7=>25% on F-1, 8=<15% on F, 9=15-40% on F, and 10=>40% on F.

[b] HR=hard red winter wheat, SW=soft white winter wheat (common head type), CL=soft white winter wheat (club head type).

Table 2. Physiologic leaf spot on flag leaves of Stephens wheat growing in soil supplemented with chloride fertilizers at two farms near Walla Walla, WA (unpublished data by Dick Smiley, Paul Rasmussen, and Don Wysocki).

Fertilizer supplement[1] and rate (lb/acre)	Casper farm mean[2] (0-4)	Casper farm leaves affected (%)	Reeder farm mean (0-4)	Reeder farm leaves affected (%)
None	1.0	83	1.3	84
Potassium chloride (150)	0.4	38	0.2	17
Potassium sulfate (160)	0.9	79	0.8	70
Calcium chloride (90)	0.3	34	0.2	14
LSD (0.05)	0.2	17	0.3	19

[1] Dry fertilizers were broadcast and incorporated after nitrogen had been shanked into the summer fallow, uniformly over the field.

[2] Mean leaf spot severity ratings during mid-June 1996: 0=no lesions, 1=<10% of leaf area covered by lesions, 2=10-25% lesions, 3=25-50% lesions, and 4=>50% lesions.

OREGON STATE UNIVERSITY EXTENSION SERVICE