SURVEY OF THE TISSUE NUTRIENT STATUS OF WINTER WHEAT IN KENTUCKY

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Abstract

A field survey conducted in western Kentucky (KY) was initiated to determine if University of Kentucky soil fertility recommendations for winter wheat production was adequate. Twenty-nine fields in 15 western KY counties were identified by county extension agents for sampling. Soil and tissue samples were collected for analysis in a 150 foot by 150 foot sampling area. Approximately 100 flag leaf samples were collected, air-dried, ground, and analyzed for N, P, K, Mg, Ca, S, B, Zn, Mn, Fe, and Cu. Soil samples were also collected the same day in the designated sampling area to 6 inches for tilled soil and 4 inches for no-till (NT) soil then analyzed for soil pH, buffer pH, P, K, Ca, Mg, Zn, and S. Five of the fields were sampled at two different growth stages to determine if growth stage influenced sample results. No major differences were observed for nutrient sufficiency at the different sampling times. Annual precipitation totals at the time of sampling ranged from 5.73 to 12.93 inches above 30 year annual means for the weather recording stations in the areas the survey was conducted. Tissue samples were below the sufficiency range for N, K, Mg, Zn, and Cu in 11, 21, 11, 10, and 4 of the fields respectively. In general, the macronutrients below the sufficiency range were attributed to abnormal environmental conditions for this wheat crop, i.e. excessive precipitation. Zinc was below the sufficiency level at 10 locations, only marginally low at several locations, and does not commonly limit wheat yields in KY. Some of the low Zn tissue values could be explained by high soil pH and high soil P levels, which can lower Zn availability. However, some fields might actually have a potential Zn deficiency that needs further investigation. Copper was below the sufficiency range at four locations, but is usually only deficient in organic soils and most likely not a concern for KY wheat production. Calcium, B, and Mn were above the sufficiency range in 2, 3, and 4 of the fields respectively. Values of Mn above the critical concentration were attributed to somewhat low soil pH values at some of the locations and the increased Mn availability in the reducing conditions present for most locations, e.g pH below 6.0 and prolonged waterlogged soils. Adjusting soil pH by liming and reasonable spring rainfall should keep Mn levels in the sufficient range. Due to the unusually wet spring and surprising results for some of the nutrients, this survey will be conducted again the following spring.

Introduction

Most plant nutrients can be added at adequate rates as determined by soil testing. However, plant tissue analyses are more reliable indicators for some secondary and micronutrient deficiencies than soil tests since Mehlich 3 soil tests have not been calibrated for wheat yield response to S, B, Cu, Mn, or Zn in KY. Tissue sampling at the latest acceptable stage (initial flowering) gives the best picture of the general nutritional status of the plant. At this plant growth stage most of the nutrient uptake has occurred (Schwab et al., 2007). When reproductive growth begins (i.e. seed or grain development) mobile nutrients contained in the plant are reallocated from the plant leaves to seed development (Mortvedt et a., 1999). Mobile plant nutrients will show deficiency symptoms on the lower, older leaves first and include N, P, K, and Mg. Immobile nutrients in the plant will tend to show nutrient deficiencies in the top, younger leaves and include Ca, B, and Zn. It has been reported that tissue testing for macronutrients is not as reliable as a good soil testing program to determine adequate fertilizer rates (Mallarino, 2011). There are many environmental influences that will determine plant uptake. For example, adding more of a nutrient that is already present in sufficient quantities will not help if ample water is absent. Poor rooting caused by wet planting can have the same effect.

Methods

In early 2011, county extension agents in western KY wheat producing areas were contacted and asked to participate in this study. Those that participated in the survey were asked to identify one or more fields in their county for tissue sampling. Twenty nine fields were sampled in 15 different KY counties. Once the field was identified, an area approximately 150 ft by 150 ft, representative of the majority of the field, was both tissue and soil sampled. Tissue samples consisted of 100 flag leaves at initial heading prior to flowering and were collected in paper bags, air-dried the same day, ground, and then analyzed for N, P, K, Mg, Ca, S, B, Zn, Mn, Fe, and Cu. Soil samples were collected the same day, to a depth of 0 to 6 inches in tilled soil and 0 to 4 inches in NT soil, that represented the identified sampling area (Thom, et. al., 2003). Soil samples were collected in a paper bag, air-dried, ground to pass a 2 mm sieve, and analyzed by University of Kentucky Regulatory Services, Soil Test Laboratory at Princeton for soil pH, buffer pH, P, K, Ca, Mg and Zn. Tissue samples and S was analyzed by Waters Agricultural Laboratory in Owensboro, KY. There were a wide range of nutrient management schemes included in the survey, but the majority of the fields followed "normal" fertility programs without additional secondary or micronutrient additions. However, a few producers in the survey had applied poultry litter, secondary nutrients (sulfur), and/or micronutrients to their fields. In five of the fields, wheat samples were collected the same day at different growth stages to compare if the different growth stages influenced the results of the nutrient concentrations. This study was initiated in 2011, as wheat was reaching maturity, to determine if there were any secondary or micronutrient deficiencies present in wheat in western KY.

Results and Discussion

Plant tissue concentrations were compared to sufficiency ranges reported in University of Kentucky AGR-92, Sampling Plant Tissue for Nutrient Analysis. Sufficiency ranges for wheat at flowering are reported in Table 1.

Table 1. Nutrient sufficiency range for small grain crops at flowering (from AGR-92).

Nutrient	N	P	K	Mg	Ca	S	B	Zn	Mn	Fe	Cu
Concentration	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
Wheat (flag leaf)	4.0 to 5.0	0.2 to 0.5	2.0 to 4.0	0.14 to 1.0	0.2 to 1.0	0.15 to 0.65	1.5 to 4.0	18 to 70	20 to 150	30 to 200	4.5 to 15

If nutrient concentrations are within this range, then no nutritional problems are expected. Values can be below this range and not exhibit nutritional deficiencies. At some value below the reported sufficiency range yields might be limited. This absolute critical value is not well defined and varies. Tissue nutrient concentrations from the sampled fields are reported in Table 2 and corresponding soil samples are reported in Table 3.

Table 2. Tissue nutrient concentration of flag leaf at flowering in 2011. Tissue concentrations highlighted in yellow were below the sufficiency range and tissue concentrations highlighted in blue were above the sufficiency range.

County (Farm or other remark) †	Plant Nutrient Concentration										
	---------------------%----------------------						----------------ppm-------------				
	N	P	K	Mg	Ca	S	B	Zn	Mn	Fe	Cu
Muhlenberg (10.2)	3.71	0.34	1.74	0.25	0.07	0.32	4	19	102	104	9
Muhlenberg (10.0)	3.67	0.33	1.99	0.24	0.59	0.32	3	18	88	94	9
Fulton (10.51)	4.29	0.27	1.34	0.37	1.15	0.36	4	25	149	120	13
Fulton (10.5)	4.22	0.28	1.50	0.34	1.07	0.41	4	32	171	154	9
Fulton (Major)	4.10	0.32	1.99	0.17	0.66	0.28	3	22	72	147	6
Graves (Crumb 10.51)	3.88	0.42	2.35	0.12	0.65	0.32	3	18	98	175	5
Graves (Crumb 10.5)	3.93	0.41	2.47	0.12	0.58	0.34	2	16	100	41	7
Graves (Williams)	4.45	0.37	2.11	0.13	0.67	0.39	9	16	66	160	8
Graves (Griffith 10.51)	4.40	0.32	2.11	0.15	0.68	0.43	2	14	106	161	2
Graves (Griffith 10.5)	4.54	0.34	2.21	0.15	0.57	0.42	2	14	99	175	3
Graves (Keith)	4.15	0.35	1.91	0.19	0.77	0.38	2	22	168	116	7
Ballard (Miller)	3.76	0.32	1.80	0.13	0.56	0.31	2	18	104	103	7
Ballard (Pace 10.4)	4.08	0.33	2.23	0.09	0.66	0.31	3	16	93	187	3
Ballard (Pace 10.5)	3.98	0.33	2.07	0.08	0.71	0.31	3	15	96	146	3
Todd (Allensville)	4.61	0.34	1.99	0.19	0.73	0.37	3	17	132	148	4
Todd (Trenton)	4.38	0.34	1.96	0.19	0.67	0.33	2	16	129	131	5
Todd (West Fork)	4.22	0.34	1.87	0.18	0.60	0.36	3	18	84	131	5
Warren (Hunt)	4.32	0.31	1.37	0.18	0.64	0.37	2	20	128	141	4
Warren (Jackson)	4.40	0.35	1.82	0.12	1.04	0.48	2	18	74	118	6
Edmonson (Barn)	4.19	0.30	2.08	0.16	0.59	0.39	2	20	88	114	10
Edmonson (Branch)	4.25	0.28	1.69	0.24	0.82	0.42	2	22	142	121	11
Simpson (Mann)	3.81	0.28	2.13	0.11	0.67	0.35	2	17	78	94	7
Simpson (Harris)	3.90	0.30	2.00	0.16	0.76	0.36	2	14	96	110	5
Hopkins (Cedar Hill)	3.91	0.30	1.97	0.11	0.56	0.30	5	15	90	131	14
Hopkins (Roberts)	4.27	0.29	2.02	0.09	0.59	0.31	3	17	87	157	6
McLean (Hayden)	4.49	0.34	1.71	0.11	0.55	0.42	3	21	164	150	5
McLean (Howard)	3.60	0.26	1.47	0.13	0.49	0.29	4	24	144	125	5
Caldwell	3.90	0.29	1.66	0.16	0.82	0.40	4	24	144	125	5
Hancock (Lincoln)	4.06	0.39	1.79	0.13	0.54	0.36	3	26	77	107	5
Hancock (Hubbard)	4.46	0.42	1.81	0.14	0.56	0.42	2	20	71	102	7
Union	3.99	0.29	1.56	0.15	0.95	0.30	3	27	69	115	9
Henderson (Street)	3.87	0.30	1.37	0.15	0.87	0.31	2	25	70	121	7
Henderson (Green)	4.03	0.31	1.36	0.16	0.88	0.35	3	29	102	132	11
Davies	4.2	0.47	1.92	0.15	0.84	0.39	5	23	199	139	5

† County (growth stage or farm identifier if multiple locations in same county)

Table 3. Soil test results collected at flowering in 2011.										
					Nutrient Content (lbs/A)					
County (Farm or other remark) †	Tillage	Additions ‡	pH	Bu pH	P	K	Ca	Mg	Zn	S*
Muhlenberg (10.2)	NT	None	6.0	6.8	75	233	2844	172	2.1	-
Muhlenberg (10.0)	NT	None	6.0	6.8	75	233	2844	172	2.1	-
Fulton (10.51)	NT	S	6.0	6.8	36	153	2988	293	5.3	18
Fulton (10.5)	NT	S	6.0	6.8	36	153	2988	293	5.3	18
Fulton (Major)	NT	None	5.9	6.7	90	415	3835	452	11.9	29
Graves (Crumb 10.51)	Tilled	S	6.5	-	113	182	3278	166	4.3	42
Graves (Crumb 10.5)	Tilled	S	6.5	-	113	182	3278	166	4.3	42
Graves (Williams)	Tilled	PL	7.0	-	300	506	4436	232	14.5	36
Graves (Griffith 10.51)	Tilled	None	6.7	-	104	234	3323	129	2.1	35
Graves (Griffith 10.5)	Tilled	None	6.7	-	104	234	3323	129	2.1	35
Graves (Keith)	Tilled	None	5.9	6.8	79	208	2558	140	2.6	24
Ballard (Miller)	NT	None	5.9	6.8	97	232	2578	130	19.4	24
Ballard (Pace 10.4)	NT	None	7.0	-	141	274	4151	87	5.0	18
Ballard (Pace 10.5)	NT	None	7.0	-	141	274	4151	87	5.0	18
Todd (Allensville)	NT	PL	6.6	-	72	226	2508	173	4.1	28
Todd (Trenton)	NT	None	6.5	-	29	147	2497	147	1.7	26
Todd (West Fork)	Tilled	FF	6.3	6.9	84	234	2846	173	4.5	26
Warren (Hunt)	NT	None	6.3	6.9	149	620	2411	116	16.6	21
Warren (Jackson)	NT	None	6.5	-	127	390	2939	145	7.2	21
Edmonson (Barn)	NT	PL	6.5	-	114	227	2907	188	9.0	34
Edmonson (Branch)	NT	PL	6.5	-	36	105	2261	295	3.8	74
Simpson (Mann)	NT	None	6.4	-	100	250	2279	124	7.9	38
Simpson (Harris)	NT	None	6.9	-	84	164	2735	122	8.4	21
Hopkins (Cedar Hill)	Tilled	None	6.2	6.9	60	166	2863	119	4.1	26
Hopkins (Roberts)	Tilled	PL	6.9	-	66	156	3802	128	4.3	31
McLean (Hayden)	NT	None	5.3	6.5	162	287	1650	133	2.1	37
McLean (Howard)	NT	PL	6.6	-	140	294	3060	157	7.1	30
Caldwell	Tilled	None	6.1	-	71	284	2810	151	5.5	27
Hancock (Lincoln)	NT	None	6.3	7	171	302	2090	82	6.3	33
Hancock (Hubbard)	NT	S	6.6	-	493	384	2986	109	6.3	33
Union	NT	FF	6.3	7	63	256	4107	325	2.8	21
Henderson (Street)	NT	None	6.4	-	174	451	3120	198	7.0	24
Henderson (Green)	NT	None	5.6	6.7	145	239	2751	392	4.5	24
Davies	NT	None	5.8	6.8	479	366	2140	114	6.5	25

† County (growth stage/farm identifier if multiple locations were sampled in the same county)
‡ None = no fertilizer additions other than N-P-K; S = sulfur; PL = poultry litter; FF = foliar fertilizer with at least one secondary or micronutrient present
* Soil tests sulfur data were generated from the same sample at a different lab.

Tissue sampling did not detect any deficiencies for P, Ca, S, B, Mn, or Fe. The most noticeable "deficiencies" in tissue nutrient concentrations occurred with N, K, Mg, and Zn (Table 2). Nitrogen applications are not based on a soil test, rather tillage practice and yield potential. The lower tissue N values maybe due to several factors. One possibility would be the loss of nitrate ($N\text{-}NO_3^-$) due to leaching if excess precipitation is present. Nitrate-N is present in many fertilizers and is formed from ammonium-N ($N\text{-}NH_4^+$) that is present in many fertilizers or formed from urea fertilizer. Precipitation was much higher than the 30 year mean for all of the weather recording stations in or near the sampled areas (Table 4) and could explain the low tissue N leaf concentration in several of the samples. Another explanation is that although tissue N concentrations were low, they were not critically low or yield limiting. And finally, tissue testing might not be well correlated for N.

Table 4. Precipitation for 2011 and 30 year mean values for weather reporting stations in or near the survey area. Values are reported in inches.

Location	January	February	March	April	Total	± 30 yr avg
Bowling Green	1.56	6.49	4.70	10.35	23.10	+ 5.73
Evansville	1.80	4.48	5.34	11.70	23.32	+ 8.81
Henderson	1.57	5.41	4.57	13.22	24.77	+ 9.63
Paducah	1.75	5.79	6.59	15.90	30.03	+ 12.93
Princeton	2.35	5.71	5.54	16.15	29.75	+11.78

Tissue analysis values for the majority of the locations indicated K levels below the sufficiency range. However, they were not excessively low and were likely not limiting grain yield. Further, rainfall was greatly above the 30 year average for surrounding weather reporting stations, particularly for April, the month of sampling. This great deviation in rainfall could have lead to lower values due to uptake issue in the saturated soils. Although tissue testing is a useful tool in diagnosing nutrient deficiencies, especially micronutrients, it is somewhat unreliable for macronutrients, particularly K. Soil test potassium (STK) was plotted against tissue K concentration and indicated that many of the tissue values were below the sufficiency range as shown by the red line at 2% tissue K concentration (Figure 1). The regression line was plotted and indicated a downward trend with increasing STK values. However the "goodness of fit" (R^2) of this data to the line was extremely low (R^2=0.0584) and signified that less than 6% of the variation of this data can be explained by this relationship. In other words, a high soil test K value does not mean that a plant will have "sufficient" K present in the tissue, or low STK does not mean that a plant will contain less than sufficient K in the tissue. Three out of the four highest K testing soils, Warren (Hunt), Henderson (Street), and Fulton (Major) had STK values of 620, 451, and 415 lbs/A with corresponding tissue concentrations of 1.37, 1.37, and 1.99% respectively. According to University of Kentucky Lime and Nutrient Recommendations (AGR-1), all three of the above mentioned locations are well above the 300 STK value indicating fertilizer additions are not recommended.

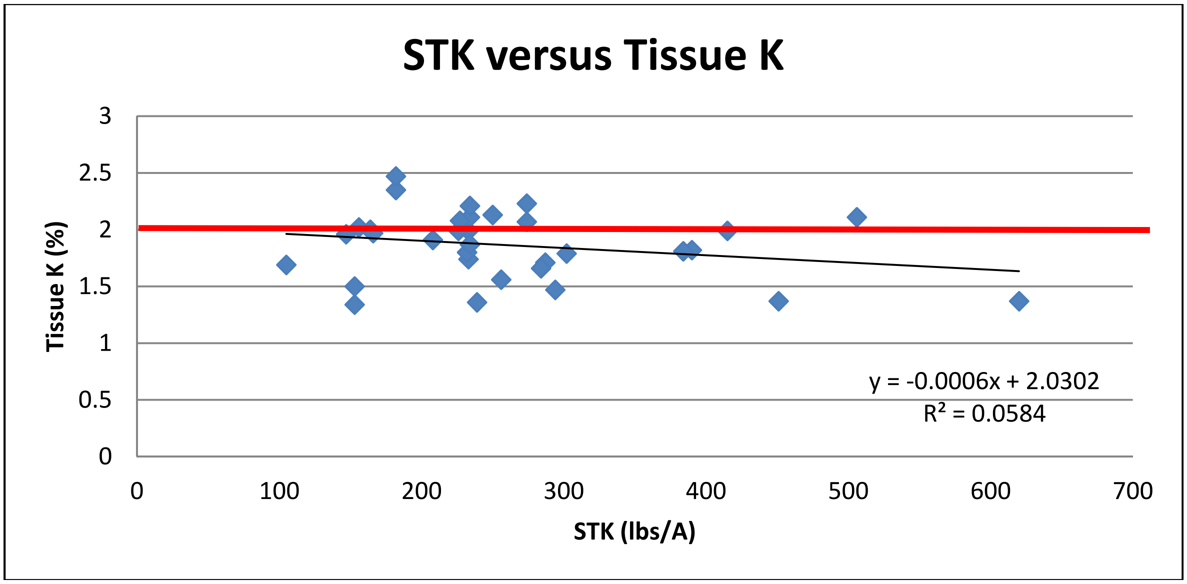

Figure 1. Tissue potassium as a function of soil test potassium.

Several tissue Mg values were below the sufficiency range. This could also be due to the same reasons suggested for N and K and doubtful that they are yield limiting to wheat. University of Kentucky Lime and Nutrient Recommendations (AGR-1) does not recommend Mg additions if soil test Mg values are above 60 lbs/A due to a low probability of a yield response. All soil test values for Mg are well above this level.

Zinc was the micronutrient that was most often below the sufficiency level. Wheat is not a crop that is very sensitive to Zn deficiency and Zn deficiency in wheat is not commonly seen in KY. The tissue Zn concentrations were usually only marginally low, the lowest 14 ppm, and most likely not limiting wheat yields. Several of the low tissue Zn levels can be explained by a high soil pH coupled with somewhat high soil test P (STP) levels, both which reduce Zn availability. A few of the samples have adequate Zn present, moderate STP levels, and reasonable pH, however are below the reported sufficiency range for wheat. These fields might have a potential nutrient deficiency that needs further investigation.

The other micronutrient that was below the sufficiency range was Cu, but like Zn generally only slightly below. The literature reports that wheat is more sensitive to low Cu than Zn, but Cu deficiencies mainly occur on organic soils (peat or muck), which are uncommon to KY. Deficiency symptoms for Cu in wheat include a light green color on young leaves, leaf tip die-back, aborted heads, and wilting at tillering and stem elongation. At the time of sampling, we looked for any apparent deficiency symptoms and none were observed. However, it has been reported that deficiency symptoms for Cu are usually not observed until yield losses are greater than 20%. Although Cu deficiencies are rare in KY and not common in mineral soil, it would be useful to further observe.

There were three nutrients in the survey that were above the critical range, Ca, B, and Mn. There are no direct toxicity problems associated with high Ca levels and no visual symptoms directly related to Ca toxicity. A potential problem that may occur with elevated Ca levels is reduced nutrient uptake by other nutrients, particularly K and Mg, due to competition with other nutrients. The slightly elevated levels of Ca in this survey are of no great concern. Boron was marginally high at two locations and well above the sufficiency range at one location. The highest testing location had received long-term poultry litter applications and likely influenced B levels to some extent. There were four tissue concentrations that were above the sufficiency range for Mn. Manganese availability is increased at lower, more acidic pH values and/or when reducing conditions are present in the soil (such as prolonged waterlogged soils). The samples that were above the sufficiency range had pH values below pH 6, with one at pH 5.3. Adjusting soil pH by liming and unsaturated soil conditions should alleviate this potential toxicity problem. Overall for this survey, there is not great concern for Mn toxicity issues for KY producers.

Sulfur fertilization has gained interest in KY in recent years. The reduction of atmospheric fallout of S due to cleaner coal-fired power plants has many producers believing that they are limited by S. Although less atmospheric S is being deposited, there still appears to be adequate S to not limit wheat growth in KY at this time. Some producers still feel the need to apply S for these reasons, as indicated by the 10% of wheat producers that applied S in this survey. All tissue samples for this survey were in the sufficiency range for S.

When sampling the same field at different growth stages, only minor differences were detected in nutrient concentrations. Of the five samples, two had values that were not in agreement as far as either being in or out of the sufficiency range. These values were only slightly different and were at the lower range of sufficiency (near the break point). This was attributed sampling variation rather than true differences due to growth stage.

Conclusions and Future Direction

Murdock and Call conducted a similar study in 1999 and 2000 and did not observe any tissue deficiencies for macronutrients. Either climatic influences (i.e. high rainfall) or insufficient yield correlation with tissue concentration were the likely contributors for the majority of our observations. However, with numerous tissue concentrations for N, K and Mg below the sufficiency range and abnormally high precipitation it would be prudent to conduct this survey for another year. No samples were below the sufficiency range for S. Murdock and Call (2000) also found no concern with S in their survey but approximately 10% (3 out of 29) of the fields sampled for our survey had applied S-containing fertilizer. Are producers applying S based on soil test, recommendations from consultants, or for other reasons? Another year of data with similar results would strengthen the fact that typically soils in Kentucky do not require S additions for maximum yield. I would also like to determine if there are any concerns with Cu or Zn, both having several low testing tissue samples during this survey.

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