MONTANA

Nutrient Uptake Patterns of Spring Wheat

By R.O. Miller and J.S. Jacobsen

At the end of the season, nitrogen (N) and phosphorus (P) were primarily located in the grain, while potassium (K) and chloride (Cl) were most abundant in stems.

When in the season does spring wheat have the greatest demands for various nutrients? In what plant parts are nutrients primarily located during the season? How does this change? To answer these questions, we conducted a study to closely monitor, during the growing season, the nutrient content in above-ground plant portions of hard red spring wheat. Although this study was conducted in 1987, the results are as relevant and instructive today as they were then, particularly as management intensity increases.

The study area was located in the Gallatin Valley of Montana. The soil was an Amsterdam silt loam. (For additional soils information, please visit >**http://www.nris.state.mt.us/nrcs/soils/**<). In the upper 12 in. of soil, analysis showed: organic matter, 2.4%; cation exchange capacity, 22.5 cmol(+)/kg; nitrate (NO_3^-)-N, 25 lb/A; Olsen P, 20 parts per million (ppm); and ammonium acetate exchangeable K, 320 ppm.

Additionally, 17 lb NO_3^--N/A was present at the 1 to 4 ft. depth. Nitrogen was applied as urea, broadcast and incorporated at a rate of 50 lb N/A. This rate was based on recommendations considering soil NO_3^- levels and a yield goal of 65 bu/A, lower than historical levels due to water limitations for irrigation.

Accumulated growing degree units (GDUs) were recorded throughout the season by subtracting the sum of the minimum and maximum temperatures and dividing by 2. The lowest allowable daily minimum temperature was set at 32°F. The highest allowable daily maximum temperature was set at 75°F.

Hard red spring wheat 'Success' was planted on April 19, 1987, at a rate of 21 seeds/ft² in 7 in. rows. The crop was sampled 16 times throughout the growing season (**Table 1**).

At each date, four locations of approximately 2.7 ft² in size were sampled. Whole plant samples were taken from Haun growth stages (HGS) 1.8 until 5.2. In subsequent samplings, plants were separated into leaves, stems, and heads. From HGS 12.1 to maturity, grain was separated from the head.

Table 1. Sampling dates and associated growth stages.

Sampling date	GDU	Haun growth stage	Description
4/29	139	1.8	1 fully expanded leaf
5/05	213	2.8	2 fully expanded leaves, early tiller
5/10	295	3.8	3 fully expanded leaves
5/14	360	4.5	4 fully expanded leaves, mid-tiller
5/19	420	5.2	5 fully expanded leaves
5/29	527	6.4	stem lengthening
6/03	579	7.0	flag leaf visible
6/08	660	8.0	flag leaf extending
6/13	749	9.2	boot swollen
6/19	849	10.2	first spikelet visible
6/29	1011	11.5	anthesis > 50% complete
7/05	1120	12.1	kernel visible, watery
7/13	1232	13.1	medium milk
7/21	1362	14.0	soft dough
7/31	1566	15.0	hard dough
8/13	1791	16.0	maturity

The accumulation of dry matter (DM) during the season is shown in **Figures 1 and 2**. Rapid DM accumulation occurred: 1) when the flag leaf was visible and extending (HGS 7.0 to 8.0), 2) during head emergence and elongation (HGS 10.0 – 11.0), and 3) during early grain fill (HGS 12.0 to 13.5). After early grain fill, leaves, stems, and heads lost dry matter, with the largest percent losses coming from the stems. The total DM produced at maturity was 6.3 t/A, with a grain yield of 91 bu/A (adjusted to 12% moisture). Approximately 38, 16, 37, and 9% of the total dry matter was in the grain, heads, stems, and leaves, respectively.

Nitrogen uptake patterns during the season are shown in **Figure 3**. It should be noted that N deficiencies did occur during the season due to above normal precipitation during flowering and grain fill, so total uptake as well as accumulation rates do not reflect those under conditions of sufficient N. This deficiency may have affected uptake patterns of all nutrients to some degree.

The most rapid N uptake occurred early in the season, from approximately two leaves fully expanded (HGS 2.0) to a fully expanded flag leaf (HGS 8.0). Another increase in N uptake rate occurred during flowering and early grain fill (HGS 11.5 to 12.0). Total N accumulated in this study was 105 lb N/A. Approximately 80, 6, 9, and 5% of this total was partitioned among the grain, heads, stems, and leaves, respectively **(Figure 1)**. Uptake and removal rates averaged 1.15 and 0.92 lb N/bu, respectively (**Table 2**).

Phosphorus accumulation rates are shown in **Figure 4**. More

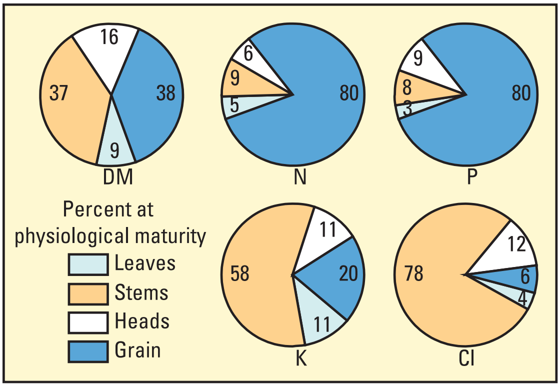

Figure 1. Percent of each nutrient partitioned in the leaves, stems, heads, and grain at physiological maturity.

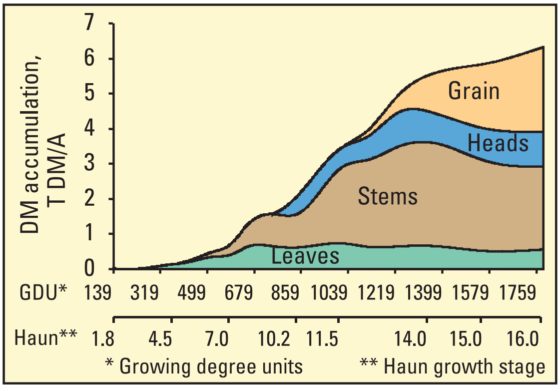

Figure 2. Cumulative accumulation patterns of DM in above-ground plant portions.

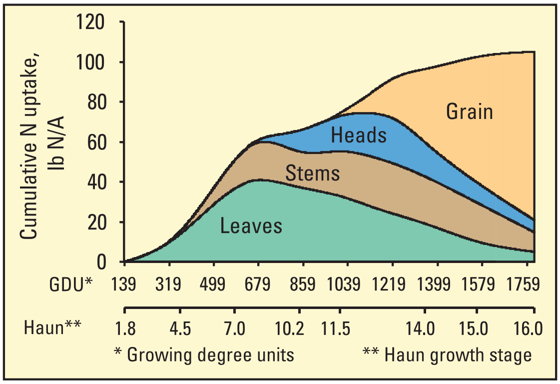

Figure 3. Cumulative N accumulation patterns in above-ground plant portions. Note: N deficiencies were observed in this study.

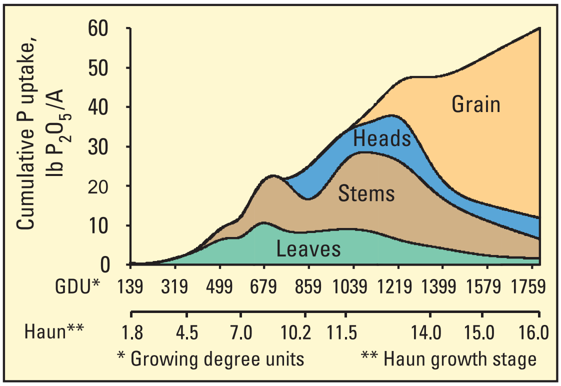

Figure 4. Cumulative P_2O_5 accumulation patterns in above-ground plant portions.

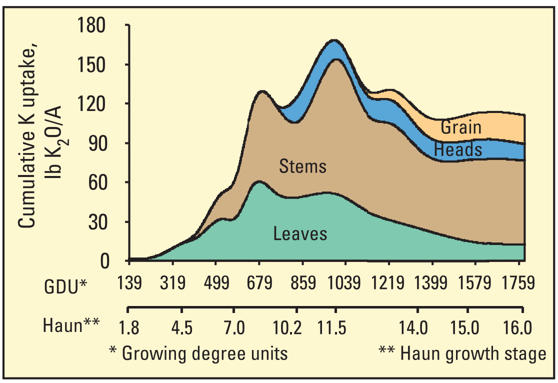

Figure 5. Cumulative K_2O accumulation patterns in above-ground plant portions.

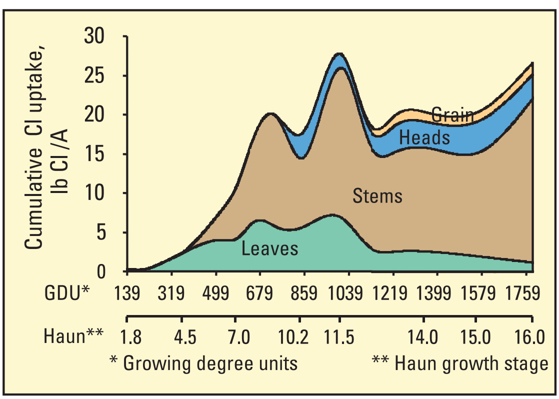

Figure 6. Cumulative Cl accumulation patterns in above-ground plant portions.

rapid uptake occurred from the time the flag leaf became visible (approx. HGS 7.0) and remained accelerated through early grain fill (approx. HGS 12.5). During the remainder of the grain fill period, P from heads, stems, and leaves was repartitioned into the grain. Total P accumulation at maturity was 60 lb P_2O_5/A, with 80, 9, 8, and 3% in the grain, head, stems, and leaves (**Figure 1**). Average uptake and removal rates were 0.66 and 0.53 lb P_2O_5/bu (**Table 2**).

Potassium and Cl had very similar uptake patterns (**Figures 5 and 6**). Both showed rapid uptake by stems from about the time five fully expanded leaves were visible (HGS 5.0), through stem elongation, until flag leaf extension (HGS 8.0). Another burst of uptake by the stems coincided with head emergence (HGS 10.0) through stem elongation and up to the beginning of flowering (HGS 11.5). Interestingly, for both K and Cl, this latter burst of uptake was the period of maximum uptake, which was 167 lb K_2O/A and 28 lb Cl/A. At the onset of anthesis, levels of both nutrients began to decline. These declines likely occurred because of nutrient leaching from physiologically mature plant portions, such as older leaves. Unlike K, Cl accumulation began increasing again in the stem from the hard dough stage (HGS 15.0) through maturity.

Levels present at maturity were near maximum uptake levels for Cl, but were well below maximum for K. Total K and Cl uptake present at maturity were 111 lb K_2O/A and 27 lb Cl/A. For K, 20, 11, 58, and 11% of this total were partitioned among grain, heads, stems, and leaves. Percent of total Cl was 6, 12, 78, and 4 for grain, heads, stems, and leaves (**Figure 1**). Uptake and removal rates at maturity were 1.22 and 0.24 lb K_2O/bu and 0.29 and 0.02 lb Cl/bu (**Table 2**). Maximum uptake rates earlier in the season were 1.84 lb K_2O/bu and 0.30 lb Cl/bu.

Table 2. Average uptake and removal rates observed in this study.

	N[1]	P_2O_5	K_2O	Cl
	- - - - - - - - - -	lb/bu	- - - - - - - - - -	
Uptake				
At maturity	1.15	0.66	1.22	0.29
At maximum uptake	1.15	0.66	1.84	0.30
Removal				
At maturity	0.92	0.53	0.24	0.02

[1]Note: N deficiencies were observed in this study.

Summary

Uptake patterns vary considerably from nutrient to nutrient. At the end of the season in this irrigated spring wheat study, most of the N and P were located in the grain. Most of the K and Cl were found in the stems. Total uptake of N and P peaked near physiological maturity, whereas maximum uptake of K and Cl occurred earlier in the season during head emergence and stem elongation, and ended with flowering. BC

Dr. Miller (e-mail: rmiller@lamar.colostate.edu) is Affiliate Professor with the Soil & Crop Sciences Dept., Colorado State University, Fort Collins. Dr. Jacobsen is Interim Dean and Director, Professor, Montana State University, Bozeman.

Corn...

(continued from page 5)

Experiment 2. This 2-year experiment was conducted during the 2002-2003 growing seasons on a site that was lower in soil test K than the previous experiment. Analysis showed that initial soil pH was 6.9; organic matter was 2.5%; Bray-1 P was high…35 ppm, and exchangeable K was 150 ppm (very high). Treatments consisted of liquid starter fertilizer rates of 0, 5, 15, or 25 lb K_2O/A applied in combination with 30 lb N, 15 lb P_2O_5, and 5 lb S/A. A 30-15-15-0 treatment was included to separate the effects of K and S. The K source used in this treatment was KCl (muriate of potash). The source of K used in all other treatments was KTS. Starter fertilizer was again applied 2 in. to the side and 2 in. below the seed at planting. Nitrogen was balanced on all plots to give a total of 220 lb/A.

Grain yield was maximized with application of 15 lb of K_2O/A in the starter (**Table 2**). Addition of 15 lb K_2O/A to the starter increased grain yield by 13 bu/A over the starter containing only N and P. No response to S was seen at this site. All combinations improved yields over the no-starter check.

Even though soil test K was in the high range, addition of K in the starter fertilizer increased early season growth and yield of corn. At this site, 15 lb K_2O/A was required to reach maximum yield. In the previous experiment on a soil much higher in available K, only 5 lb K_2O/A was needed to maximize yields.

Conclusion

Nutrient management in conservation tillage systems can be challenging. The increased amounts of crop residue present in these systems can cause early season nutrient deficiency problems that the plant may not be able to overcome later in the growing season. Early season P and K nutrition is essential for maximizing corn yield. In these experiments, addition of K to starters containing N and P has been shown to improve early season growth, nutrient uptake, earliness of maturity, and yield of corn grown in a long-term ridge-tillage production system. BC

Dr. Gordon is Professor, Department of Agronomy, Kansas State University, North Central Kansas Experiment Field; e-mail: bgordon@oznet.ksu.edu.