Biomass Accumulation and Nutrient Uptake of Cereals at Different Growth Stages in the Parkland Region of Saskatchewan

S. S. Malhi[1], A. M. Johnston[1], J. J. Schoenau[2] and Z. H. Wang[1,3]
[1]*Agriculture and Agri-Food Canada, Research Farm, Highway 6 South, P.O. Box 1240, Melfort, Saskatchewan, Canada S0E 1A0 (Phone: 306-752-2776 Ext. 230; Fax: 306-752-4911; E-mail: malhis@agr.gc.ca)*
[2]*Department of Soil Science, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 5A8*
[3]*College of Resources and Environmental Sciences, Northwestern Sci-Tec University of Agriculture and Forestry, Yangling, Shaanxi 712100, P. R. China*

Abstract

Field experiments were conducted with spring wheat (cv. AC Barrie - CWRS and cv. AC Taber - CPS), barley (cv. AC Oxbow - malt and cv. AC Lacombe - feed) and oats (cv. CDC Boyer or CDC Pacer) in 1998 and 1999 at Melfort, Saskatchewan, Canada, to determine biomass accumulation and nutrient uptake in cereal crops at different growth stages, and their relationship. All cereal crops followed a similar pattern of biomass and nutrient accumulation, which increased at early growth stages, reached at maximum and then decreased at late growth stages. Cereal crops usually reached their maximum biomass at late milk to full ripening stages (72-90 days after emergence), although some cultivars had a several days difference between the two years. Maximum biomass accumulation rate was 164-204 kg $ha^{-1}d^{-1}$ for wheat, 211-308 kg $ha^{-1}d^{-1}$ for barley and 185-217g $ha^{-1}d^{-1}$ for oats. Maximum uptake of nutrients usually occurred at beginning of flower to late milk (63-82 days after emergence) in both years. Maximum accumulation rate of N, P, K and S was 2.0-4.7, 0.3-0.4, 2.4-5.1 and 0.3-0.5 kg $ha^{-1}d^{-1}$ for wheat, 2.4-5.2, 0.3-0.5, 3.1-7.6 and 0.4-0.8 kg $ha^{-1}d^{-1}$ for barley, and 2.7-3.6, 0.3, 4.2-4.7 and 0.4-0.5 kg $ha^{-1}d^{-1}$ for oats, respectively. Both seed yield and nutrient uptake were lower in 1999 than in 1998, due to differences in weather conditions in the growing season in the two years. In summary, maximum nutrient accumulation rate occurred earlier than maximum biomass accumulation rate, and maximum nutrient uptake occurred earlier than maximum biomass. This indicates that in order to get high seed yields, there should be sufficient supply of nutrients to ensure higher nutrient uptake rate at tillering to stem elongation growth stage first, then a higher biomass accumulation rate at early to late boot growth stage, a greater nutrient uptake at beginning of flower to late milk growth stage, and a greater biomass at late milk to full ripening growth stage. This also suggests that sufficient supply of nutrients from soil/fertilizers at early growth stages is of great importance for high-yield crop production systems.

Background

In small grains, seed yields are usually related to biomass production, or the harvest index. An understanding of crop growth and the relationship between grain yield and biomass can assist in attaining yield improvements through better agronomic practices. The increased focus on optimizing yield response to nutrient inputs and the need to ensure balanced nutrition has increased demand for information on biomass accumulation, nutrient concentration and nutrient sufficiency levels of crops. For whole and seasonal mineral nutrients requirements of crops, fertilizer scheduling and synchronizing nutrient supply with nutrient demand of the crops, it is essential to determine the exact amount of nutrient uptake over the growing season. The objective of this study was to quantify the seasonal biomass accumulation and nutrient uptake pattern of cereal crops under conditions of optimal nutrition.

Materials and Methods

Field experiments were conducted in 1998 and 1999 on a Black Chernozemic soil at Melfort, Saskatchewan. The precipitation in the growing season (from seeding to harvesting) was 150 mm in 1998 and 190 mm in 1999. Treatments included crops of spring wheat (cv. AC Barrie - CWRS and cv. AC Taber - CPS), barley (cv. AC Oxbow - malt and cv. AC Lacombe - feed) and oats (CDC Boyer in 1998 and CDC pacer in 1999) arranged in a randomized complete block design in 4 replications. Test area was tilled prior to seeding to incorporate herbicides (Edge), and then was banded with a blend of N, P, K and S fertilizers to meet all nutrient deficiencies at a rate 25% higher than maximum recommended rates for these nutrients. All crops were seeded with a hoe type air drill on May 11, 1998 and May 24, 1999. Crop biomass samples were collected beginning at 3 weeks post-emergence, and continuing every 1 week until full maturity (7 samplings in 1998 and 8 samplings in 1999). At each sampling, the crop growth stage was estimated using growth staging scales of Tottman (1977). The plant samples were ground for laboratory analysis of total N, P, K and S. Data were plotted to illustrate the progressive accumulation of crop biomass and nutrients, and decline in nutrient concentration.

Results

Table 1 and Figure1

Biomass accumulation, nutrient concentration and nutrient uptake varied with crop, cultivar and year. Cereal crops usually reached their maximum biomass at late milk to full ripening growth stages (72-90 days after emergence), with maximum biomass accumulation rate of 164-204 kg ha^{-1} d^{-1} for wheat, 211-308 kg ha^{-1} d^{-1} for barley and 185-217g ha^{-1} d^{-1} for oats.

Figures 2, 3, 4 and 5

Maximum uptake of nutrients usually occurred at early flowering to late milk growth stages (63-82 days after emergence), and maximum accumulation rate of N, P, K and S, respectively, was 2.0-4.7, 0.3-0.4, 2.4-5.1 and 0.3-0.5 kg ha-1 d^{-1} for wheat, 2.4-5.2, 0.3-0.5, 3.1-7.6 and 0.4-0.8 kg ha-1 d^{-1} for barley, and 2.7-3.6, 0.3, 4.2-4.7 and 0.4-0.5 kg ha^{-1} d^{-1} for oats.

Maximum nutrient accumulation rate occurred earlier than maximum biomass accumulation rate, and maximum nutrient uptake occurred earlier than maximum biomass. This indicates that in order to get high seed yields, soil has to be able supply sufficient amount of nutrients to ensure that plants have higher nutrient uptake rate at tillering to stem elongation stage. This also suggests that sufficient supply of nutrients at early growth stages is of great importance for high yield.

Table 1. Days to achieve maximum biomass, biomass at harvest, grain yield and harvest index of cereal crops in the field experiments at Melfort, Saskatchewan in 1998 and 1999

Year	Crops	Cultivar	Maximum biomass ($kg\ ha^{-1}$)		Biomass and grain yields at harvest ($kg\ ha^{-1}$)		
			Day	Biomass	Biomass	Grain yields	Harvest indexes
1998	Wheat	AC Barrie	80	7624	7147	2556	35.8
	Wheat	AC Taber	84	7647	7457	3687	49.4
	Barley	AC Oxbow	79	9410	8607	4664	54.2
	Barley	AC Lacombe	82	9818	9426	5131	54.4
	Oats	CDC Boyer	76	8763	7173	3498	48.8
1999	Wheat	AC Barrie	78	8514	7726	1140	14.8
	Wheat	AC Taber	90	9575	9566	2638	27.6
	Barley	AC Oxbow	80	10966	10932	3338	30.5
	Barley	AC Lacombe	72	11142	9952	3384	34.0
	Oats	CDC Pacer	86	9647	9617	1903	19.8

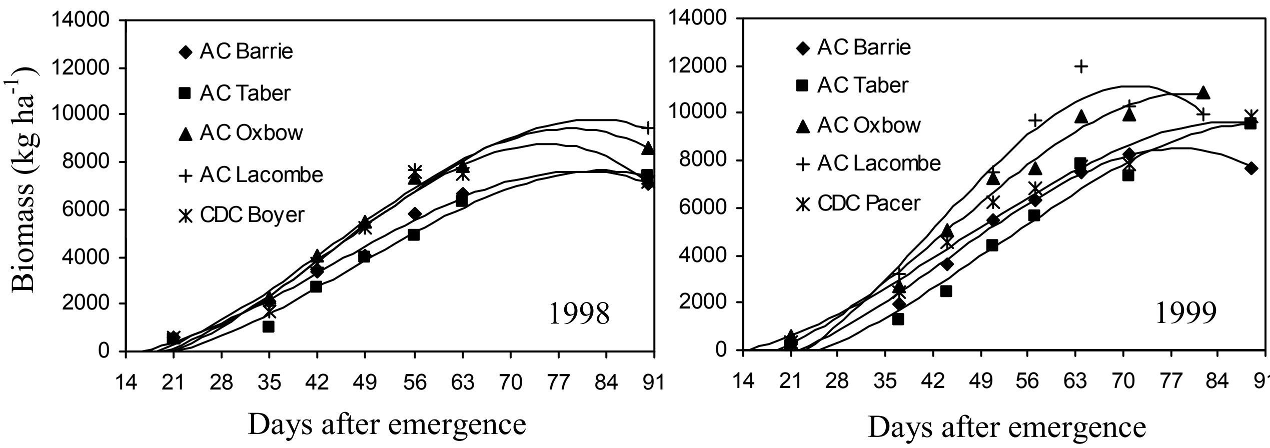

Figure 1. Changes of biomass (kg DM ha^{-1}) with days after emergence in the field experiments at Melfort, Saskatchewan.

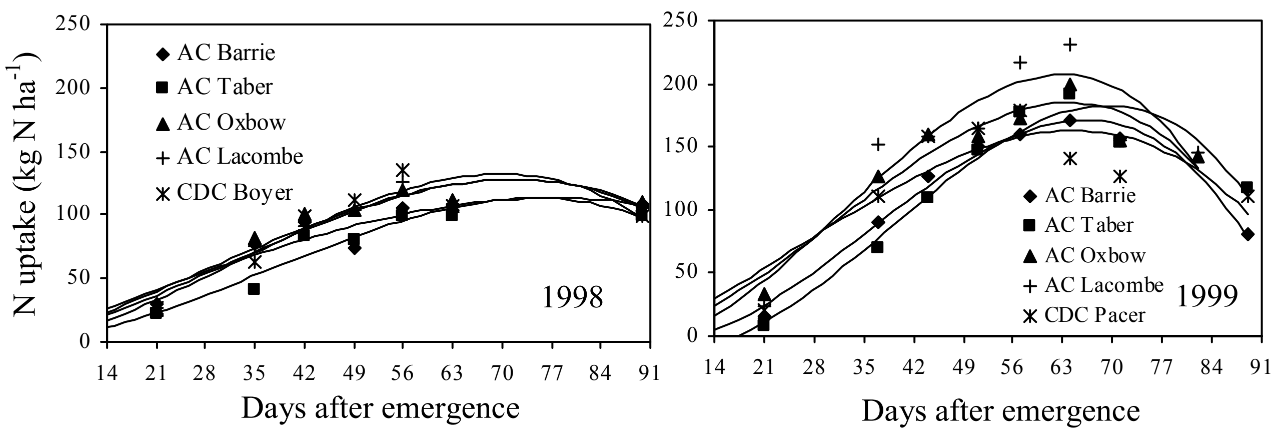

Figure 2. Changes of N uptake (kg N ha^{-1}) with days after emergence in the field experiments at Melfort, Saskatchewan.

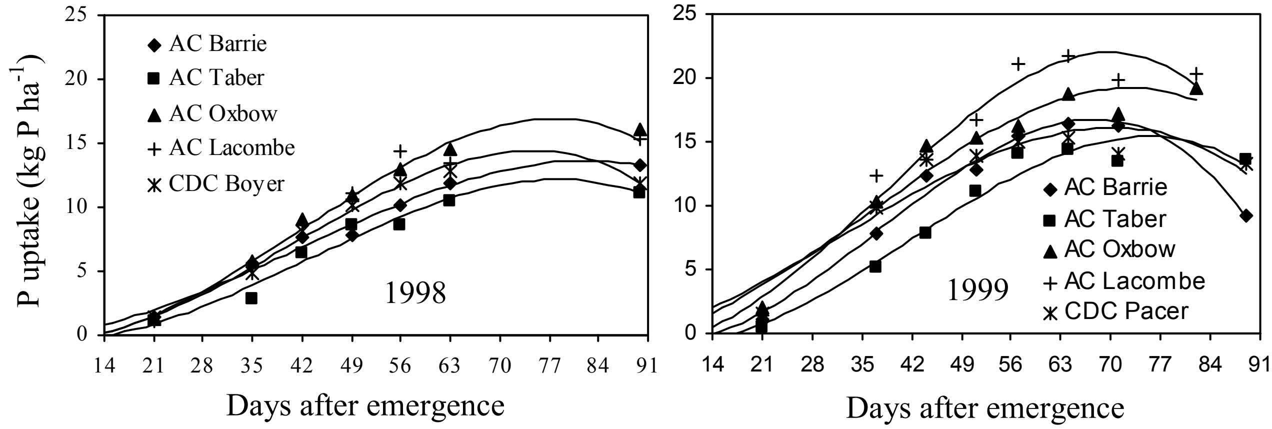

Figure 3. Changes of P uptake (kg P ha^{-1}) with days after emergence in the field experiments at Melfort, Saskatchewan.

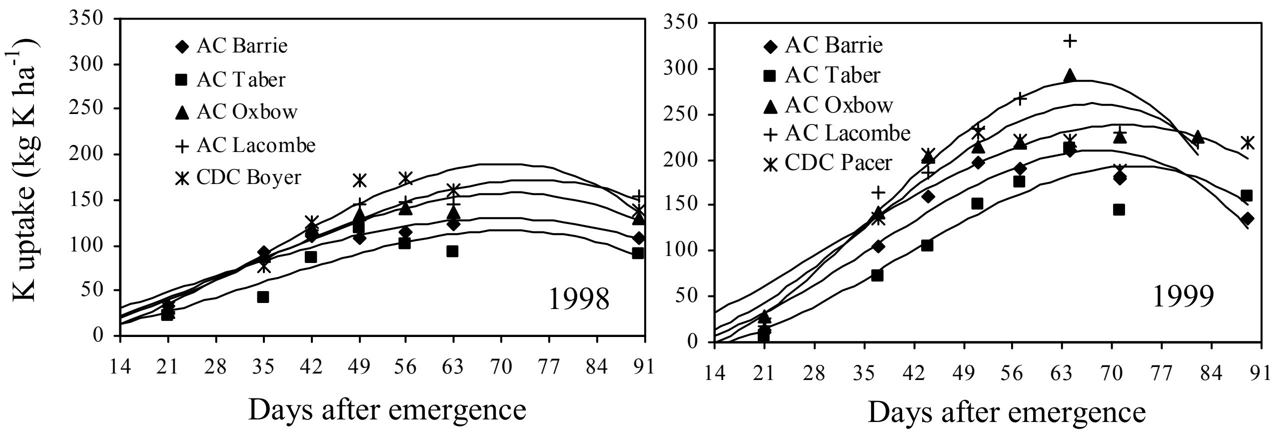

Figure 4. Changes of K uptake (kg K ha^{-1}) with days after emergence in the field experiments at Melfort, Saskatchewan.

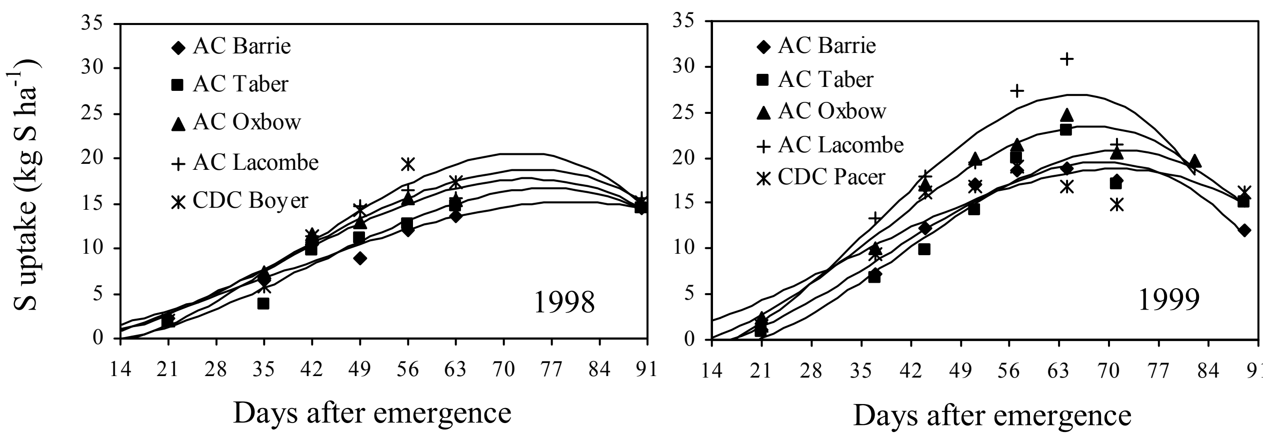

Figure 5. Changes of S uptake (kg S ha^{-1}) with days after emergence in the field experiments at Melfort, Saskatchewan.