NUTRIENT ACCUMULATION AND PARTITIONING BY GRAIN CORN IN MANITOBA

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ABSTRACT

High grain yield of corn was produced in a year with normal heat unit and precipitation accumulation without periods of heat or moisture stress. Nutrients varied not only in magnitude of uptake, but in rate, timing and partitioning within the plant. Magnitude of nutrient uptake was: K_2O > N > P_2O_5 > Mg > Ca =S, Fe >>> Zn = Mn > B > Cu. Some nutrients were repartitioned within the plant as the cob and kernels developed (N, P, K, S, Zn, and Fe) while others remained in vegetative structures and did not appear to translocate to grain (Ca, Mg, Mn, Cu and B). The corn crop accessed soil nitrate-N to a depth of 120 cm.

INTRODUCTION

It is recognized that high yields of corn require a substantial supply of nutrients. Many of the crop nutrient uptake and removal amounts used in crop extension and advisory work were developed from studies involving high levels of nutrient use in high yield environments. For example, nutrient uptake patterns were established from a maximum yield study in New Jersey which yielded 307 bu/ac of corn (Karlen et al, 1988). There is interest in validating the level of nutrient accumulation and partitioning in the plant under Manitoba's more modest yield potential environment.

MATERIALS AND METHODS

A block of commercial corn was bulk seeded on the Hyland Seeds research farm near Carman, Manitoba. The soil is a well-drained Neuenburg loam soil. A 2225 CHU rated hybrid, HL 2093, was seeded on May 7 at 68,000 seeds/ha (27,500 seeds/acre). Weeds were controlled with an application of Accent, Banvel and Merge surfactant.

Based on initially high test levels from a whole field soil test, no fertilizer was applied at seeding. Through soil and tissue analysis and chlorophyll measurements, a shortfall in nitrogen was identified and supplemental urea nitrogen was side-dressed on June 25 at 66 kg N/ha. Subsequent tissue and chlorophyll analysis indicate plant sufficiency had been achieved.

In order to measure nutrient uptake and accumulation, whole plant samples were taken at selected growth stages during the season (Table 1). Sampling was according to a randomized complete block design with 3 replicates. Cumulative corn heat units (CHU) and rainfall following seeding is reported in Table 1.

Table 1. Corn sampling stages and cumulative rainfall and corn heat units (CHU) from planting on May 7.

Sampling Date	Growth stage and description	CHUs 2003	CHUs Normal	Precipitation mm 2003	Precipitation mm Normal
June 17	V4 – four leaves fully emerged	656	641	113	88
July 4	V8 – eight leaves fully emerged	1009	1007	147	138
July 18	VT - tassel emerged	1305	1335	175	180
July 25	R1 – silks emerging	1475	1497	175	192
Aug 7	R2 – blister stage of kernel	1784	1792	211	221
Aug 20	R5 – early dent stage of kernel	2124	2067	234	250
Sept 25	R6 - physiological maturity	2694	2617	305	316

At sampling the plants were cut at ground level, separated into plant portions (leaf, stalk, tassel, ear, cob and kernels), dried, ground and submitted for full nutrient analysis by AgVise Laboratories. Once the ear developed kernels, the ear was separated into kernels and cob, including husk.

Phosphorus (P) and potassium (K) levels are converted to the oxide forms (P_2O_5 and K_2O) to equate to "fertilizer nutrient" values. The daily rate of dry matter and nutrient accumulation was determined based on the interval between samplings. Full results are reported by Heard, 2004.

Soil sampling was conducted at monthly intervals during the growing season to depths of 120-150 cm to track nitrate-N changes in the soil.

RESULTS

Corn Heat Unit (CHU) accumulation and rainfall was very similar to that normally expected (Table 1). Corn yield was higher than normal, with combine harvested yield from the entire field ranging from 7.5 to 8.05 t/ha (119-128 bu/ac). These high yields reflect the yield potential when there are few stress periods during the season.

Total dry matter accumulation at harvest was 15317 kg/ha. The grain portion was 8290 kg/ha (156 bu/ac) with a harvest index of 54%. The remaining biomass at maturity consisted of 13% leaves, 18% stalk and tassel and 14% cob and husk. The dry matter accumulation pattern (Figure 1) was similar to that observed by other researchers (Karlan et al, 1988) and did not exhibit any apparent periods of stress. Rate of dry matter accumulation was greatest for leaves between V8 to VT stages, for stalk and tassel between the VT to R1 stage and for grain at the R2 to R5 stage of kernel filling. The greatest whole plant dry matter accumulation rate occurred during the R2-R5 stage at 346 kg dry matter/day exclusively moving into grain.

Total aerial nitrogen (N) accumulation was 139 kg/ha, with 73% or 102 kg/ha in the grain. Peak accumulation in leaves was 43 kg N/ha at VT stage, in stalk and tassel was 24 kg N/ha at R1 and R2 stages and in cob and grain was 109 kg N/ha at R6. Two features of N content are observed in Figure 2. The most obvious is the gradual decline in vegetative N content during the reproductive stage as nitrogen is partitioned from leaves and stalk to the grain, which accumulates N at 4.71 kg/ha/day during the R2-R5 stage. The second feature is the decline in the rate of N accumulation between VT and R1 in late July. Other researchers observed this as an actual loss in whole plant N content (Karlan et al, 1988). They postulate the loss of aerial N may be due to: volatilization loss because there is no sink, feedback inhibition stopping N uptake by the plant or loss as shed pollen during pollination. Another possible explanation is translocation to roots, which were not measured in this study. Brace root development is initiated just prior to VT stage, and such growing roots may be acting as a temporary N sink during this period.

Whole plant N uptake rate was between 1.97 and 2.15 kg N/ha/day at stages V8 to VT and between stages R1 to R5, respectively. The whole plant N uptake declined to ½ kg/ha/day during R5 to R6 as most N movement resulted from repartitioning within the plant.

Total aerial phosphorus (P) accumulation was 81 kg P_2O_5/ha, with 85% or 69 kg P_2O_5/ha in the grain. At maturity P was allocated as follows: 6% in leaves, 5% in stalk and tassel and 89% in cob and grain. Phosphorus is a mobile nutrient in the plant and a general decline in leaf and stalk P content occurred during reproductive stages with the ear, then grain acting as sink (Figure 2). The peak in plant P uptake rate occurred during grain filling between R2 and R5, at a rate of 2.15 kg P_2O_5/ha/day.

Total aerial potassium (K) accumulation was 145 kg K_2O/ha, with 25% or 36 kg K_2O /ha in the grain. At maturity 13% of potassium remained in leaves, 45% in stalk and tassel and 41% in cob and grain (Figure 2). Potassium content in leaves was greatest at 62 kg K_2O/ha at the VT stage and was moved out of leaves throughout the reproductive stages. Maximum potassium content in the stalk occurred at maturity with 65 kg K_2O/ha. The peak in plant K uptake rate occurred during vegetative growth, with accumulation rates of 3.18 kg K_2O/ha/day between V4 to V8 and 3.53 kg K_2O/ha/day between V8 to VT. Potassium content of the plant is commonly observed to decline after physiologic maturity during crop dry down, due to leaching of soluble K out of plant tissues. Our sampling concluded prior to this occurrence.

Sulphur (S) uptake by the plant was only 12 kg S/ha, with 8 kg S/ha or 67% in grain, 2 kg S/ha in leaves, 1 kg S/ha in stalk and tassel and 1 kg S/ha in cob and husk (Figure 2). Rate of uptake was similar through the season, with the exception being the lack of aerial accumulation between VT and R1 as observed with N and K. Sulphur content of leaves declined slightly during the reproductive and grain filling stages.

Calcium (Ca) uptake, although similar in magnitude to sulphur at 12 kg Ca/ha, was exclusively partitioned into leaves (82%), stalk and tassel (12%) and cob and husk (6%) with no measurable amounts in grain (Figure 2). Magnesium uptake was 29 kg Mg/ha with 45% present in grain, 34% in leaves, 14% in stalk and tassel and 7% in cob and husks. Similar to calcium, no magnesium appeared to be translocated from leaves and stalk to grain (Figure 2).

Total accumulation of micronutrients was small; 213 g Zn/ha, 530 g Fe/ha, 194 g Mn/ha, 38 g Cu/ha and 80 g B/ha. Some 79% of total zinc was contained in the grain compared to 25% of Fe, 11% of Mn, 21% of Cu and 31% of B. Iron and Zn continued to accumulate until maturity, whereas Mn, Cu and B content actually declined between R5 and R6 (Figures 3).

With the exception of the July 4 sampling, nitrate levels declined consistently with each sampling date (Table 2). By harvest, nitrate levels in the surface 60 cm were very low (10 kg nitrate-N/ha). It appears that this corn crop extracted soil nitrate to the 120 cm depth. Nitrate levels were unchanged at the 120-150 cm depth.

Table 2. Change in nitrate-N levels during the season.

Soil depth	June 2	July 4	August 21	September 30
	Nitrate-N kg/ha			
0-15	17	25	18	6
16-30	20	21	8	2
31-60	34	20	6	2
61-90	31	22	13	8
91-120	32	18	14	12
121-150	-	17	14	16

REFERENCES

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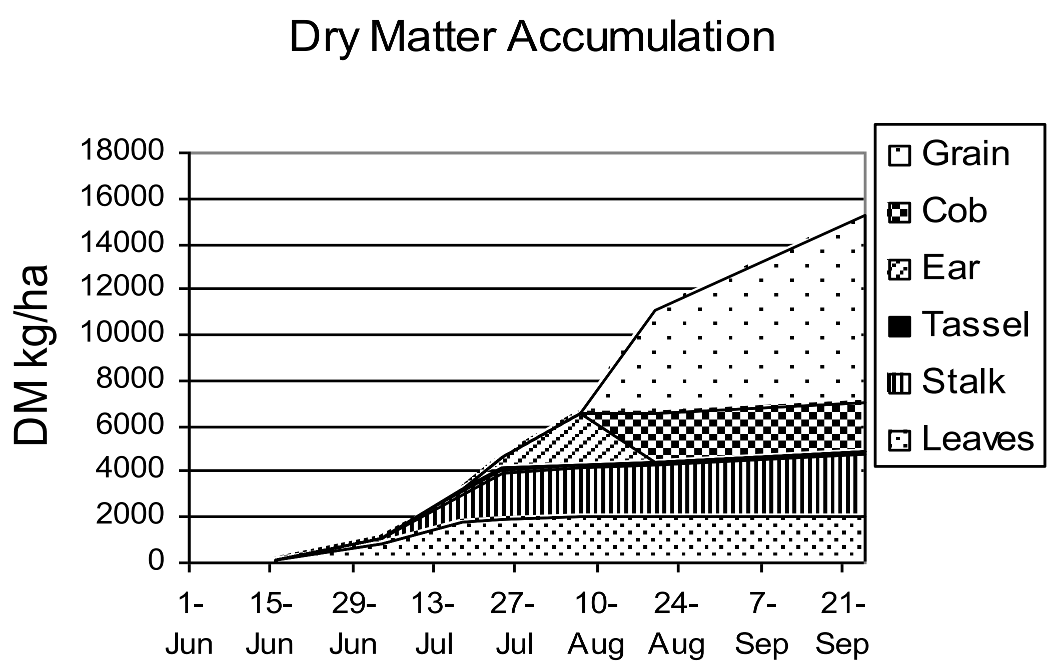

Growth Stage V4 V8 VT R1 R2 R5 R6

Figure 1. Aerial dry matter accumulation of corn.

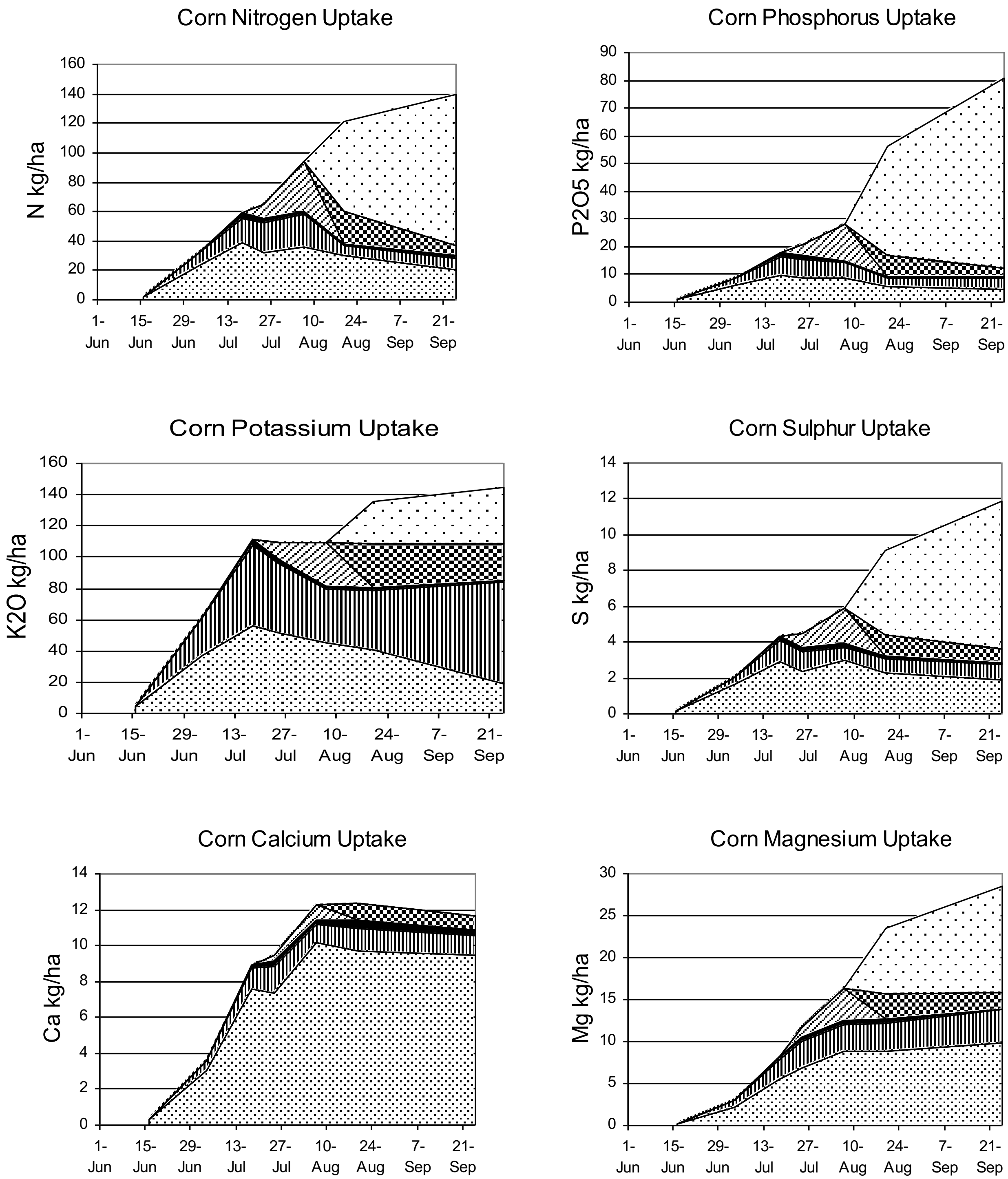

Figure 2. Nutrient accumulation by corn.

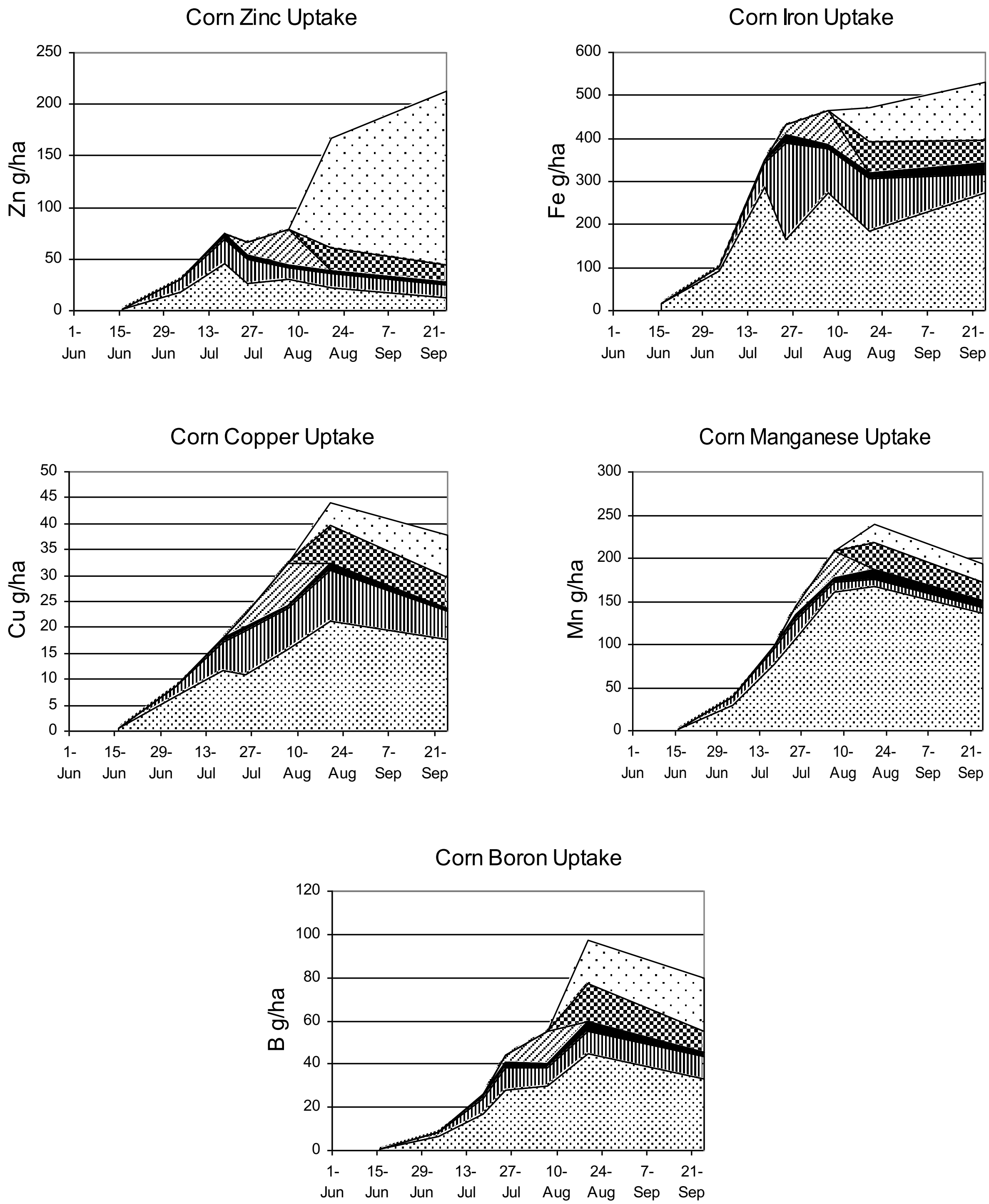

Fig. 3. Micronutrient accumulation by corn.