ASSESSING NUTRIENT UPTAKE AND ACCUMULATION IN HOP PRODUCTION

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ABSTRACT

Hop growing practices and market demands have both evolved in the past 30 years. Oregon hop growers need updated information on the timing and quantity of nutrients in order to better time nutrient applications to achieve optimal yields and quality and reduce environmental losses. During the 2020 growing season, total biomass and nutrient concentration samples were taken at seven time points in three commercial hop yards of Cascade cultivar. Mean N, P, K, and S accumulation were 114, 16, 95, and 24 lb/ac/season, respectively. Cones accumulated proportionally more P, K, S, and Zn than vegetative biomass, and less Mg and Ca. Maximum nutrient uptake for most nutrients was observed around early July and reached over 2 lbs/ac/day for N uptake. N uptake rates declined relatively sharply as the season progressed, while for other nutrients the rate of uptake slowed, but not as dramatically. Data reported here is the first of a three year study that aims to generate uptake and accumulation data that can be expressed relative to a range of growth and development metrics (calendar date, growing degree accumulation and growth stage) to provide growers with robust data that can be translated between sites and years.

INTRODUCTION

Commercial hop production practices and cultivars have changed in the past 25 years and there is a need for updated nutrient management information under cotemporary practices. Current nutrient accumulation and uptake curves are only available for nitrogen (N). Current regional nutrient management guides from Oregon State University and Washington State University date back to the 1990's or earlier (Gingrich et al., 2000, Roberts, S. and Nelson, S.E., 1961). In the meantime, market forces and breeding efforts have led to a proliferation of new varieties, many of which are higher yielding than when this original nutrient work took place. At the same time, winters may be less severe and with altered precipitation patterns; together these factors have potentially shifted nutrient uptake profiles and demands. In parallel, management practices have evolved, and many hop yards now use drip irrigation where they have the capacity to dose fertilizer throughout the growing season. Recent data shows that excessive or late (post-bloom) N applications may cause a decline in cone quality with a decrease in alpha and beta acids and an increase in cone NO_3^- (Iskra et al., 2019). In response to these changing practices and increasing knowledge, growers and the hop industry have expressed a need for updated data on the rate and timing of nutrient uptake and improved methods of determining in-season nutrient status. Growers are also interested in micronutrient demands, in particular for zinc, boron, and iron.

METHODS

Three hop yards of Cascade cultivar, located in Marion County, Oregon, were selected for this project. All yards were under drip irrigation. In each yard, three sampling zones were established and considered as replicates. In total, there were three yards with three replicates each, n=9. The following data was collected in the 2020 season: pre-season and post-harvest soil samples (March 12 and September 21, respectively) at 0-8" and 8-24", biomass and nutrient concentration samples at seven time points, petiole N, P, K at four time points, nutrient availability as measured by plant root simulator probes, hop yield and hop cone quality. At time points 1 and 2, whole plant biomass was collected; at time points 3-6 biomass was partitioned into side arms and main stem; at the final sampling (i.e. harvest) biomass was split into side arms, side arm cones, main stem and main stem cones. Growers followed their own nutrient program for rates and timing based on individual goals and constraints, soil tests, and consultation with agronomists. The goal was to evaluate nutrient uptake and availability under business as usual standard practices (Table 1).

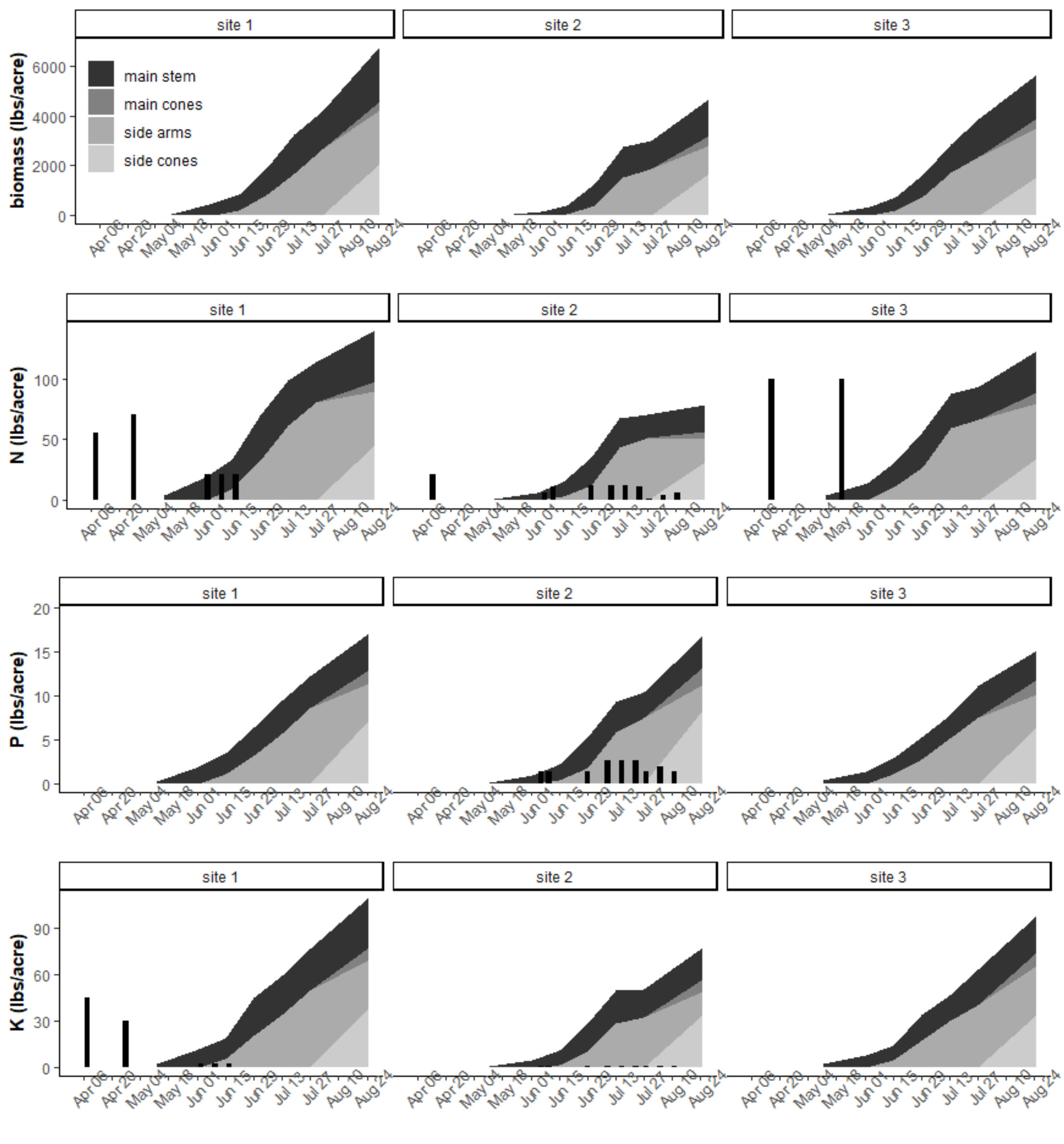
Table 1. Yard structure and management across the three sites in 2020

Yard Structure	
yard size	10-15 acres
yard age	planted 2013-2017
irrigation	drip
row cover cropping (winter/spring/summer/combo)	barley or diverse mix
row cultivation (approx. number of passes)	1.5 to 5 passes/season
2020 Management	
Mechanical pruning	28-Feb to 25-Mar
Chemical pruning	10-Apr to 28-Apr
training date	5-May to 7-May
number of fertilizer applications	2 to 12
irrigation sets per season	15 to 72
total irrigation inputs (gal/ac)	126,000 to 314,000 gal/acre
harvest date	26-Aug to 7-Sep
yield (bales/ac)	8 to 9.4 bales
2020 fertilizer application totals	**lbs/acre**
N	127 to 200
P	0 to 36
K	0 to 83
S	25 to 58
Mg	0 to 11
Ca	0 to 4
B	0 to 1

RESULTS AND DISCUSSION

Whole plant biomass accumulation ranged from 4675 ± 1020 lb/ac to 6781 ± 639 lb/ac, with a mean across sites of 5701 ± 1341 lb/ac (Figure 1 and Table 2). Whole plant N accumulation ranged from 78 ± 15 lb/ac to 140 ± 13, with an average across sites of 114 lb/ac N. Following N, K and Ca had the highest accumulation with around 100 lb/ac seasonal uptake. Mean P, S, and Mg were 16 ± 4, 24 ± 8, and 9 ± 2 lb/ac, respectively. Complete seasonal uptake data for all nutrients is given in Table 2.

Figure 1. Biomass, N, P and K accumulation and partitioning at each site (n=3 per site). Data was collected at seven time points. Immature cones were present at the sixth time point but were not separated, thus their biomass is included in the side arm and main stem category at this point. Fertilizer rate and timing is indicated as bars on the cumulative N, P and K uptake graphs.



The rate of nutrient accumulation and partitioning to side arms vs main stem and later to cones vs vegetative biomass did not differ greatly among the sites (Figure 1 and Table 2). Across all sites, side arm tissue accounted for the majority of uptake and nutrient accumulation, accounting for between 60-63% of biomass across the sites. Much of the side arm uptake could be attributed to the large amount of cones produced on side arms, accounting for more than 80% of cone biomass. Analysis of the cone biomass alone showed that on average 37% of biomass at harvest was in the cones, however the cones accounted for 56% of P, 45% of K and 44% of S and Zn, demonstrating that higher rates of these nutrients are being allocated to cones. In contrast, Mg and Ca were disproportionately allocated to vegetative biomass (Table 3).

Table 2. Nutrient accumulation at harvest in the different biomass components. Values are the means and standard deviation across all three sites (n=9).

	main stem	*stdev*	main cones	*stdev*	side arms	*stdev*	side cones	*stdev*	whole plant	*stdev*
					lb/ac					
biomass	1830	*530*	360	*190*	1740	*550*	1770	*390*	5700	*1340*
N	33	*12*	8	*5*	36	*14*	37	*8*	114	*34.5*
P	4	*1*	2	*1*	4	*1*	7	*2*	16	*3.9*
Mg	8	*3*	1	*1*	9	*4*	6	*1*	24	*7.6*
K	26	*7*	8	*5*	26	*9*	35	*8*	95	*22.8*
Ca	41	*12*	3	*2*	39	*14*	19	*4*	103	*26.3*
S	2	*1*	1	*0*	3	*1*	3	*1*	9	*2.3*
B	0.011	*0.002*	0.002	*0.000*	0.011	*0.002*	0.009	*0.002*	0.031	*0.006*
Fe	0.040	*0.015*	0.009	*0.007*	0.051	*0.022*	0.046	*0.011*	0.146	*0.047*
Zn	0.007	*0.004*	0.002	*0.000*	0.007	*0.002*	0.007	*0.002*	0.020	*0.006*

Table 3. Biomass and nutrient accumulation in cones only. Values are the mean across all three sites and sampling zones (n=9)

	main cones			side cones			all cones	
	lb/ac	% total biomass	% cone biomass	lb/ac	% total biomass	% cone biomass	lb/ac	% total biomass
biomass	360	6%	17%	1770	31%	83%	2130	37%
N	8	7%	18%	37	32%	82%	45	39%
P	2	13%	22%	7	44%	78%	9	56%
Mg	1	4%	14%	6	25%	86%	7	29%
K	8	8%	19%	35	37%	81%	43	45%
Ca	3	3%	14%	19	18%	86%	22	21%
S	1	11%	25%	3	33%	75%	4	44%
B	0.002	7%	20%	0.009	29%	80%	0.011	36%
Fe	0.009	6%	16%	0.046	32%	84%	0.055	38%
Zn	0.002	11%	25%	0.007	33%	75%	0.009	44%

Analysis of uptake rates, showed that peak uptake for most nutrients occurred in early July (Figure 2). As the season progressed, N uptake rates dropped quite sharply, while that of P and K remained relatively high. Given that the cones accumulated greater amounts of P and K and were developing during this latter part of the growing season, this likely drove the continued higher uptake of these nutrients. Peak K uptake occurred a bit earlier than with other nutrients and then remained steady around 1 lb/ac/day through the season. We do not have a good explanation for the drop in micronutrient uptake rates seen in B and Fe at the end of July; this may be an artifact of sampling, dust deposition, or may reflect true changes in plant demand.

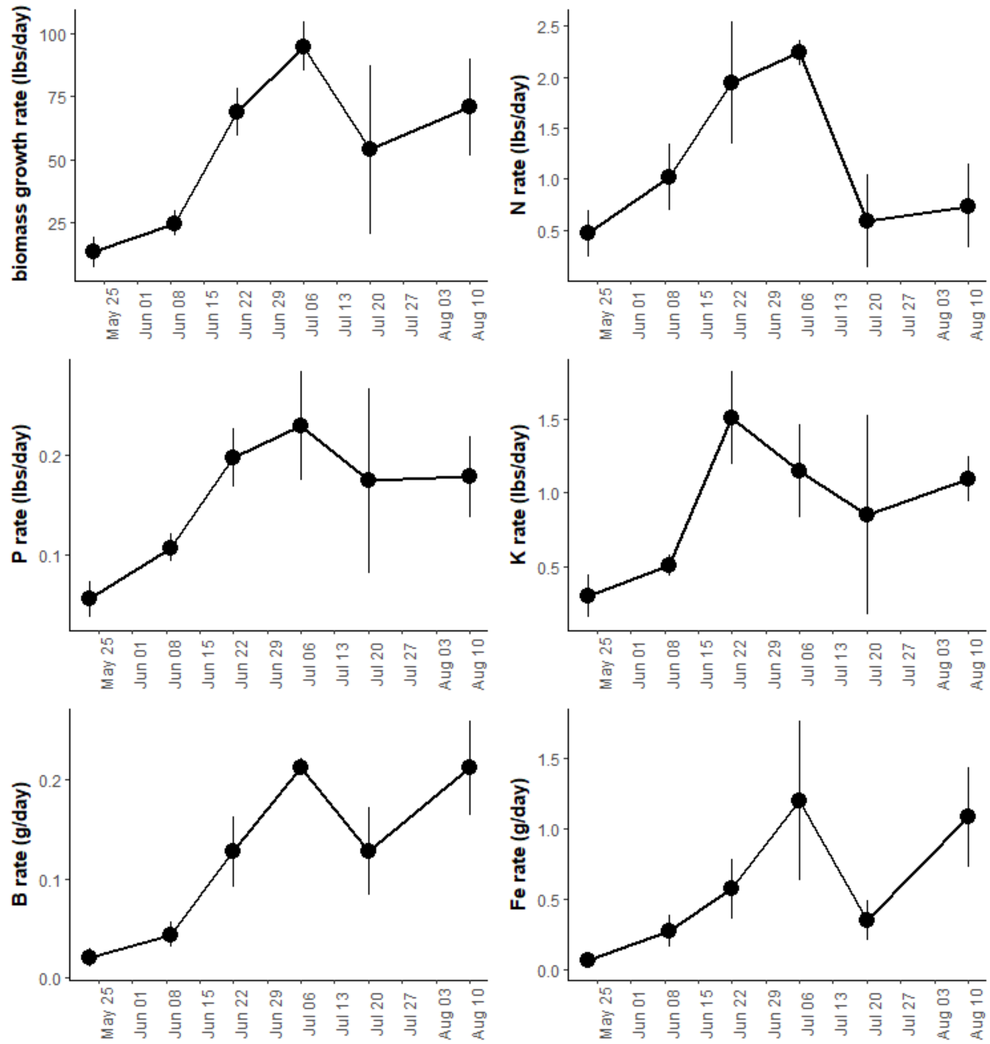
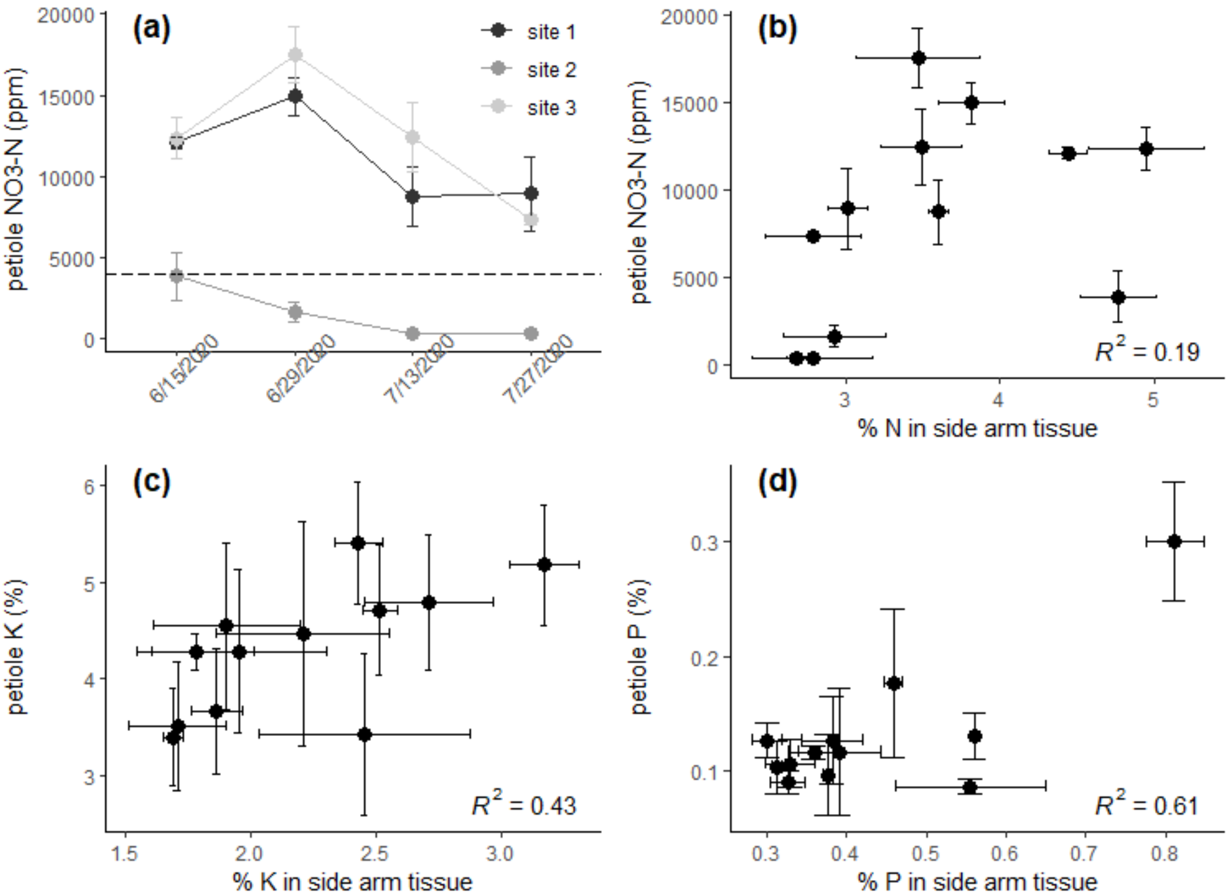


Figure 2. Biomass and nutrient uptake rates. Rates are on a per acre basis and are the mean ± stdev across the three sites.

The standard petiole sampling time for hops is around mid-June or when the hops are between ¾ to fully at the wire, indeed this was right at our first petiole sampling date on June 15th. While data to support sufficiency or deficiency thresholds based on petiole tissue tests is scant for hops, we do have thresholds for NO3-N and these indicate a deficiency when less than 4000 ppm at this mid-June timing. Based on this, petiole data at site 2 was right on the cusp of being considered N deficient, while the other two sites were likely in N excess (Figure 3). Better linkages between petiole tissue data to plant deficiency/sufficiency status remains a need. We found that relationships between petiole tissue data and side arm tissue concentrations showed modest correlations for K, relatively poor correlations for N and likely for P when a potential outlier is excluded (Figure 3). More data and further analysis are needed to determine how petiole tissues can be better used as means to evaluate in-season nutrient status.

Figure 3. (a) NO_3-N in petiole tissue at the three sites over the four sampling points. (b-d) Comparison of side arm biomass nutrient concentration and petiole nutrient concentrations. A comparison with main stem tissue revealed similar patterns.



The aim nor design of this study was to compare practices between sites. However, some information can be gleaned from looking at the individual site date and management practices. Site 2, had the lowest rate but highest number off N applications at 127 lb/ac/season over 12 applications compared to 188 lb/ac/season over 5 applications and 200 lb/ac/season over two applications at sites 1 and 2, respectively. It is likely that site 2 was N deficient at times during the growing season, evidenced by petiole tissue data from this site. While grower reported yields were a bit lower for this site, hop cone total oil content, alpha and beta acid content (measures of quality) were all highest at this site. Further, hop cone NO_3^- concentration, a negative attribute for end consumers, was the lowest at this site. While preliminary, this data does indicate possible trade-offs between N application strategy, yield, and quality. Data from subsequent years will be used to build robust nutrient uptake and accumulation curves to help better guide timing and rate of fertilizer applications.

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