Characteristics of Nutrient Uptake by Grape

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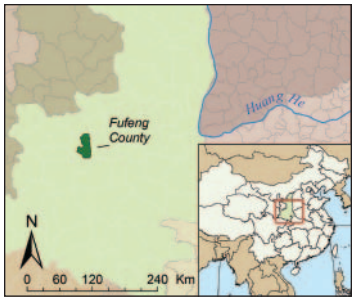
Nutrient uptake was examined in an intensive year-round study of a 7-year old grape orchard in Fufeng County in order to guide nutrient management for grape production in Shaanxi Province. Macronutrient accumulation was identified according to plant development stage, which provides insight into the periods of peak nutrient demand and appropriate timings of fertilizer application.



Grape is considered a major cash crop in Shaanxi. Most recently available statistics place its total area at 17,700 ha and its total grape production at 220,000 metric tons (t). Nutrient uptake by grape has not been as intensively studied as cereal crops and previous studies in grape have mainly focused on yield/quality responses to fertilizer applications (Abha et al., 1995; Li et al., 1995; Zhou et al., 2002). Thus, the nutrient requirement of grape has not been clear, which restricts the implementation of science-based nutrient management in the crop. The objective of this study was to investigate N, P, and K uptake and its distribution in grape plant parts during an entire growing season.

The study was conducted in Fufeng County, located on the western reaches of the Guanzhong Plain. The soil type for the selected grape orchard was Eum-orthic anthrosols (using Chinese Soil Taxonomy). According to routine soil analysis methods described in Lu (2000), soil organic matter, total N, Olsen-P, and exchangeable K (ammonium acetate extractable) were 9.9 g/kg, 1.05 g N/kg, 7.8 mg P/kg, and 120 mg K/kg. Grape plants were selected from a 7-year old Red-Globe grape orchard planted at a row spacing of 1 m with 2.5 m between each plant. Red-Globe is a table grape variety introduced from North America. It has long shelf life, is easy to transport, and is suited to planting in arid or semiarid areas with trellises. Grapes (fruit) in this orchard were first harvested 3 years after planting. Average annual fertilizer rate applied during the last 3 years before sampling, and the year of sampling, was 635 kg N/ha, 308 kg P_2O_5/ha, and 216 kg K_2O/ha. In this traditional system, fertilizers were applied within a band 20 cm deep and 60 to 70 cm around the tree. All P and K fertilizers and 50% of the N fertilizer were applied basally in September after grape harvest; 30% of the N was applied in March and the remainder in June, during the start of new shoot growth and fruit development.

Red-Globe is a table grape variety introduced from North America. It has a long shelf life, is easy to transport, and is suited to planting in arid or semi arid areas with trellises. Samples were taken from this orchard for analysis.

Samples were taken from three typical plants at six different growing stages including: March 30 (sprouting and early foliage growth), May 10 (young fruit growth), June 30 (new shoot growth and fruit development), August 20 (fruit expansion), September 30 (fruit maturity), and November 30 (dormancy). At each sampling, fruits, leaves, new tops, branches, trunks, and roots were separated. Root samples included all within a radius of 50 cm around the trunk and a 100 cm depth. Enzymatic activity within all plant samples was destroyed by oven heating at 100 to 105 °C for 15 minutes. Samples were dried to a constant weight at 70 to 80 °C, ground, and digested in concentrated sulfuric acid (Lu, 2000). The solutions were analyzed for N and P by Flow Injection Analyzer (Emteryd, 1991), and K was determined by flame photometry (Lu, 2000).

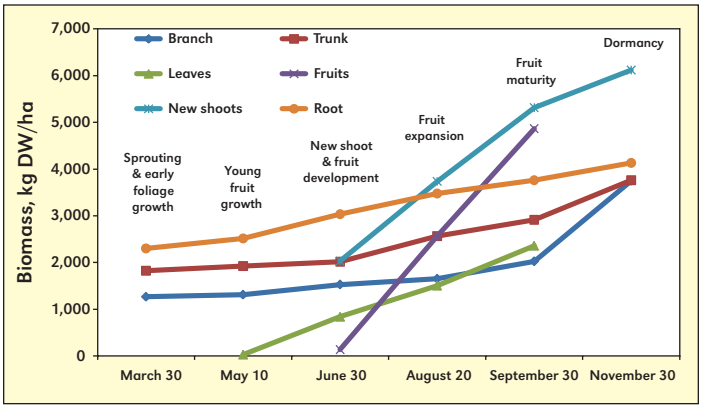


Figure 1. Changes in biomass of different plant parts during growing period of grape plants.

Researchers gathered whole plant samples throughout the season to determine biomass and nutrient accumulation within each plant part. Students are shown cutting branches for samples.

Biomass, measured as dry matter weight (DW), of the main trunks and roots gradually accumulated from March to November **(Figure 1).** The biomass of branches also increased at a gradual rate before harvest, but this was followed by a period of more rapid growth. Leaf biomass accumulated rapidly from May to September. New shoots grew most rapidly between June 30 and September 30 which coincided with the period of rapid fruit development. Total average biomass of grape plants, not

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

including fruits, increased from 5,391 to 17,760 kg DW/ha between March 30 and November 30.

Grape plants accumulated an average of over 102 kg N/ha between March 30 and November 30 **(Table 1)**. This N was fairly evenly distributed between fruit (31.6%) and leaves (34.3%), while new shoots received 27.5% of total annual plant N uptake. Established plant parts including branches, trunks, and roots accumulated a small amount of N. The total N that remained in the plant after harvest was 34.1% of total N uptake, while the remainder was removed with the leaves and harvested fruit.

Nutrient removal in grape leaves and fruit represented about 66% of total annual plant demand for N, 45% for P, and 58% for K.

Grape plants accumulated 33 kg P_2O_5/ha during the growing season **(Table 2)**; 36.1% of this was distributed to fruit, followed by new shoots which received 27.5% of total P uptake. Results also showed that 45.4% of total plant P uptake was removed by leaves and fruit, while 54.5% remained in the grape plant.

Total annual K accumulation amounted to over 140 kg K_2O/ha **(Table 3)**, which was mainly distributed between fruit (45.8%) and new shoots (22.5%). Fruit and leaves removed 58% of total K uptake, thus 42% of the total remained in the plant.

This study highlights three distinct stages for nutrient uptake by grape plants, including: 1) the period between sprouting/early foliage growth and new shoot/fruit development; 2) the period between early fruit development and fruit expansion; and 3) the period after fruit expansion up to fruit maturity. These respective periods saw 38%, 28.7%, and 28.8% of the total N accumulation, 22.4%, 29.4%, and 31.2% of P accumulation, and 26.2%, 45.7%, and 16.6% of K accumulation. Given these seasonal distributions, it can be generally stated that while soil N supply is equally critical throughout the entire growth phase of grape plants, it is particularly important for soil P supply to increase gradually and extend throughout the entire fruit production phase. Lastly, K supply must meet maximum plant demand that occurs just prior to fruit expansion.

Table 4 compares this study's results for NPK requirements of 1,000 kg of Red-Globe grape fruit with previous work using other varieties (National Investigation and Cooperation Network on Grape, 1993; Qin et al., 2001; Zhang and Ma, 2006). Regardless of the variation between studies, all agree that grape plants require significant quantities of K followed by N then P. Although it is currently difficult to quantify fertilizer recommendations for grape orchards by soil testing, the site's nutrient balance can be monitored and annual nutrient removal by

Table 1. Nitrogen accumulation and distribution (kg N/ha) in various parts of grape plants.

	Sampling date						
Plant part	March 30	May 10	June 30	Aug. 20	Sept. 30	Nov. 30	Net accumulated N
Leaves	-	2.9	18.8	30.1	35.1	-	35.1
Fruits	-	-	6.2	20.4	32.3	-	32.3
New shoots	-	-	20.1	21.8	28.1	28.1	28.1
Branch	4.4	4.9	5.3	5.9	6.2	7.0	2.6
Trunk	5.7	5.7	5.8	6.2	6.6	7.2	1.5
Roots	20.2	17.7	13.0	14.2	19.8	22.9	2.7
Total plant	30.3	31.2	69.2	98.6	128.1	65.2	102.3

Note: Net accumulated N in leaves, fruits, and new shoots equal to total accumulated in the last sampling. Net accumulated N in branches, trunks and roots equal to N accumulation in the last sampling value minus N accumulation in the first sampling value.

Table 2. Phosphorus accumulation and distribution (kg P_2O_5/ha) in various parts of grape plants.

	Sampling date						
Plant part	March 30	May 10	June 30	Aug. 20	Sept. 30	Nov. 30	Net accumulated P_2O_5
Leaves	-	0.1	2.3	2.9	3.1	-	3.1
Fruits	-	-	0.3	5.4	11.9	-	11.9
New shoots	-	-	4.7	7.7	8.3	9.1	9.1
Branch	1.0	1.4	2.0	1.2	1.2	4.5	3.5
Trunk	0.7	0.6	1.1	1.1	1.1	2.3	1.6
Roots	9.2	8.2	7.9	9.7	12.7	13.0	3.8
Total plant	10.9	10.3	18.3	28.0	38.3	28.9	33.0

Table 3. Potassium accumulation and distribution (kg K_2O/ha) in various parts of grape plants.

	Sampling date						
Plant part	March 30	May 10	June 30	Aug. 20	Sept. 30	Nov. 30	Net accumulated K_2O
Leaves	-	0.4	12.3	13.6	17.2	-	17.2
Fruits	-	-	2.6	43.0	64.3	-	64.3
New shoots	-	-	20.7	34.4	28.3	31.6	31.6
Branch	7.0	5.6	4.9	8.1	8.8	15.4	8.4
Trunk	7.3	6.2	6.2	11.4	12.5	14.4	7.1
Roots	19.7	20.0	24.1	24.5	27.2	31.5	11.8
Total plant	34.0	32.2	70.8	135.0	158.3	92.9	140.4

Table 4. Nutrient requirement to produce 1,000 kg grapes.

		Nutrient requirement, kg/1,000 kg grape			
Cultivars	Plant age, yrs.	N	P_2O_5	K_2O	N: P_2O_5: K_2O
Red-Globe	7	4.05	1.84	7.80	1:0.32:1.37
Ju Feng[1]	6	3.91	2.31	5.26	1:0.59:1.35
Shuangyou [2]	12	8.44	12.76	13.13	1:0.39:1.15
Cabernet Sauvignon[3]	5	5.95	3.95	7.68	1:0.66:1.29

[1] National Investigation and Cooperation Network on Grape, 1993
[2] Qin et al., 2001
[3] Zhang and Ma, 2006

To achieve a more complete assessment of seasonal nutrient distribution, below-ground plant parts were considered. Although annual accumulation of N in roots was relatively minor, amounts for P and K were more significant. This is an example of roots for sampling

senesced leaves and harvested fruits can be supplemented by applying appropriate amounts of nutrients. Assuming that two-thirds of accumulated nutrients are derived from fertilizer and using fertilizer N, P, and K use efficiencies of 50%, 40%, and 50%, respectively, the recommended application rate would be 136-55-187 kg N-P_2O_5-K_2O/ha. According to the characteristics of nutrient uptake during the growing season, fertilizer N should be split evenly between the three stages of nutrient demand described above. About 50% of this P recommendation should be supplied prior to fruit expansion and 70% of K recommendation should be applied prior to the flourishing of new shoot growth.

As is indicated, the recommended rates of N, P, and K in this study are significantly lower than those that have been traditionally used, especially in the case of N and P. Although this suggests N and P have been overused for grape production in Shaanxi, it still needs to be confirmed whether this new recommendation, rationalized according to seasonal crop demand, can sustain high yielding grape production and soil nutrient balances. BC

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Conversion Factors for U.S. System and Metric

Because of the diverse readership of *Better Crops with Plant Food*, units of measure are given in U.S. system standards in some articles and in metric units in others…depending on the method commonly used in the region where the information originates. For example, an article reporting on corn yields in Illinois would use units of pounds per acre (lb/A) for fertilizer rates and bushels (bu) for yields; an article on rice production in Southeast Asia would use kilograms (kg), hectares (ha), and other metric units.

Several factors are available to quickly convert units from either system to units more familiar to individual readers. Following are some examples which will be useful in relation to various articles in this issue of *Better Crops with Plant Food*.

To convert Col. 1 into Col. 2, multiply by:	Column 1	Column 2	To convert Col. 2 into Col. 1, multiply by:
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.54
	Area		
2.471	hectare, ha	acre, A	0.405
	Volume		
1.057	liter, L	quart (liquid), qt	0.946
	Mass		
1.102	tonne[1] (metric, 1,000 kg)	short ton (U.S. 2,000 lb)	0.9072
0.035	gram, g	ounce	28.35
	Yield or Rate		
0.446	tonne/ha	ton/A	2.242
0.891	kg/ha	lb/A	1.12
0.159	kg/ha	bu/A, corn (grain)	62.7
0.149	kg/ha	bu/A, wheat or soybeans	67.2

[1]The spelling as "tonne" indicates metric ton (1,000 kg). Spelling as "ton" indicates the U.S. short ton (2,000 lb). When used as a unit of measure, tonne or ton may be abbreviated, as in 9 t/ha. A metric expression assumes t=tonne; a U.S. expression assumes t=ton.