Phosphorus Absorption and Accumulation in Apple

By Yan'an Tong and Fan Hongzhu

Phosphorus concentration and accumulation in field-grown Fuji apple trees showed that fall accumulated P was used to meet demand during fruit expansion in late July. Fertilizer P should be applied in the fall and just prior to fruit expansion.

Phosphorus fertilization has an important impact on the yield and quality of upland apple production in northwest China. Past study has focused on this relationship, but little information is available on plant uptake, translocation, and distribution of P in apple trees. This article outlines a comprehensive study on the dynamics of P uptake and distribution within Fuji *(M. micromalus. Makino)* apple trees.

A trial was arranged in Qishan County, on the southern portion of the Loess Plateau in Shaanxi, which is well suited to quality apple production and provides a good representation of typical upland apple production in northwestern China. Cultivated apple area in Shaanxi has reached 0.426 M ha, producing 6.0 M t—27% of China's and 10% of the world's apple production.

The orchard site was comprised of 9-year old Fuji apple trees with a row spacing of 2 m and 3 m between trees. The trial was carried out during 2004 and 2005. Samples were taken from three trees at similar stages of development on five dates. Sampling in 2004 took place on March 26 (sprouting and foliage growing period), April 30 (young fruit stage), July 30 (fruit expansion stage), September 21 (fruit maturity), and on January 15, 2005 (tree dormancy). Samples of fruit, foliage, new tops, branches, trunks, and roots were collected each time. Root samples included all those within a 100 cm depth and a radius of 100 cm around the trunk. The cortex and xylem within the trunks and roots were divided and analyzed separately. Enzymatic activity was destroyed by placing plant parts in an oven set at 100 to 105 °C for 15 minutes, and then samples were dried to a constant weight at 70 to 80 °C. Samples were ground

Demonstration orchard for balanced fertilization.

Apple tree sampling.

and digested with concentrated sulfuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2). The P content of the resulting solution was measured colorimetrically.

Results from the study showed a sharp increase in biomass from the early growth period in March to fruit maturity and harvest in September (**Figure 1-A**). Tree growth after this period slowed significantly. Apple trees accumulated an average of 37.1 kg P/ha within the 11-month study period, in which P destined for fruit and foliage amounted to 7.9 kg P/ha. Very little P was removed by trees between March and late July (**Figure 1-B**). This agrees with previous results (Tagliavini et al., 1998) as initial P demand resulting from new leaf and branch growth is apparently translocated from sources stored the previous season. Trees absorbed the majority of P after July 30. The days between July 30 and September 21 represented the peak period of demand for P. Subsequent plant samples collected up to mid-January suggest continued P uptake and accumulation within the primary storage organs (**Figure 1-B, Table 1**).

Abbreviations and notes for this article: P = phosphorus; M ha = million hectares; M t = million metric tons; m/d = month/day

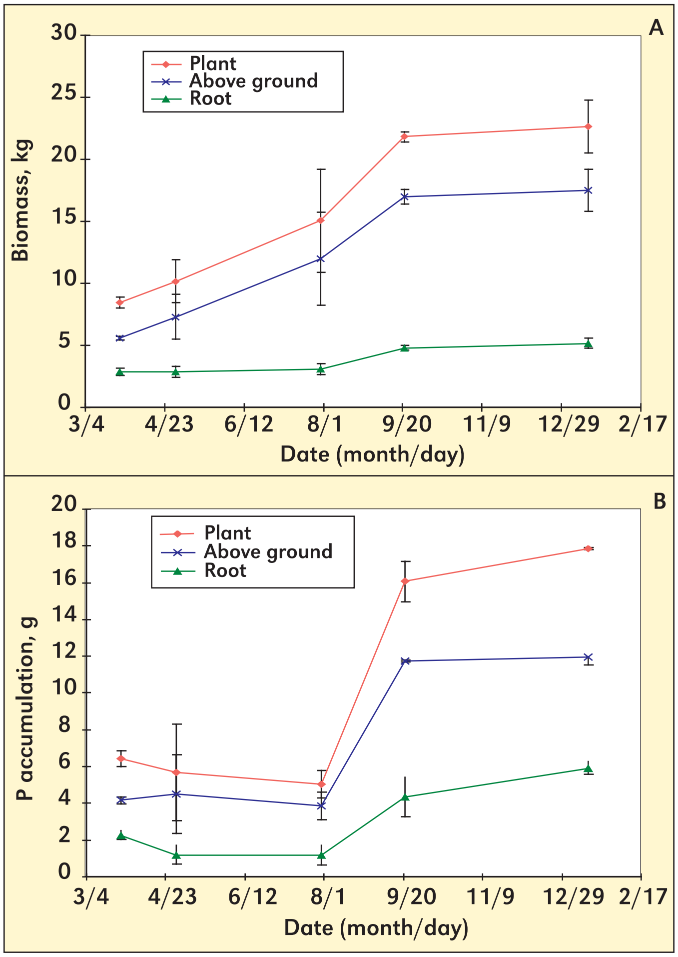

Figure 1. Annual changes of biomass (A) and P accumulation (B) in apple trees.

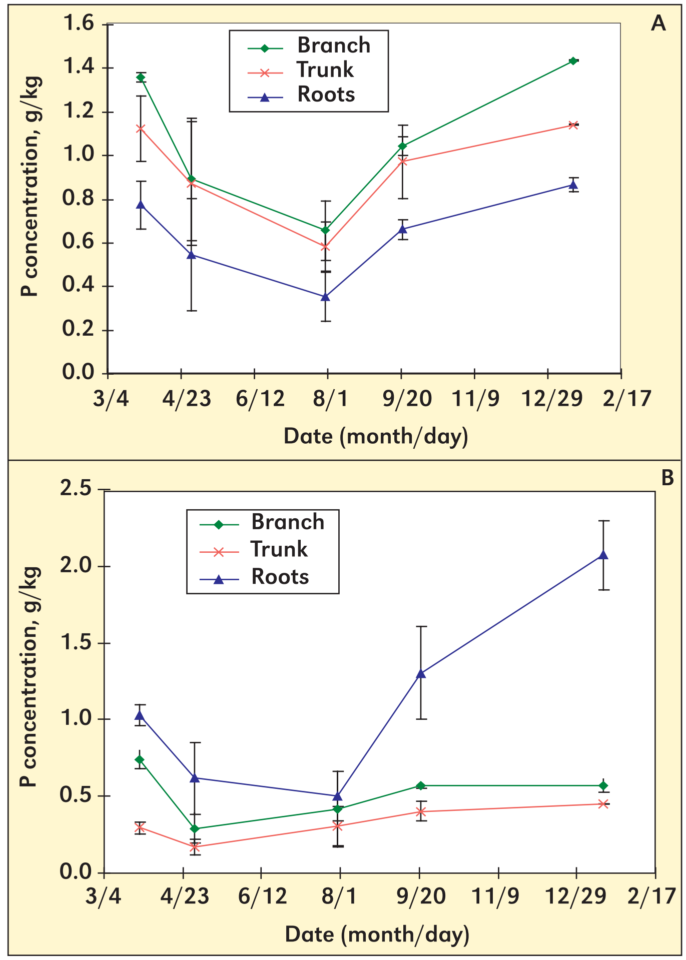

Figure 2. Dynamic changes of P content in organs of cortex (A) and xylem (B)

From July to January, the amount of P accumulated in branches, trunks, and roots increased by 410%, 325%, and 397%, respectively (**Table 1**). Phosphorus accumulation within these storage organs reached a maximum at dormancy in January. At this point, branches, trunks, and roots contained 36%, 22%, and 34% of the total plant P, respectively. This ranking of P accumulation within the primary storage organs agrees with results reported for N storage (Grassi et al., 2003; Frak et al., 2002).

The dynamics of annual P concentrations within collected cortex and xylem are provided in **Figure 2-A and 2-B**. Phosphorus within the cortex of branches, trunks, and roots declined from March to July by 51%, 48%, and 55%, respectively, and reflect the required P redistribution to active growing tissues. Plant P uptake is signaled as cortex P content began to increase in all three organs between the fruit-expanding period in late July and dormancy in January. Tree branches had the highest cortex P during all growing stages, followed by the trunks and roots.

Phosphorus within the xylem of branches, trunks, and roots also decreased during early growth (**Figure 2-B**). Concentrations dropped to their lowest levels in April and then rose after July, especially in roots. In contrast to cortex P measurements, during all growing stages xylem P concentrations were highest within the roots, followed by the branches and then trunks.

Measurements of cortex and xylem P concentrations support the conclusion that apple tree roots take up little P in the spring and early summer. The decrease of P concentrations in the cortex and xylem highlights the early spring and sum-

Table 1. Phosphorus accumulation in apple tree organs at different sampling times.

	Sampling date, m/d				
Organ	3/26	4/30	7/30	9/21	1/15
Fruits, g/tree	–	0.12 ±0.02^{c}	0.42 ±0.38^{bc}	2.84 ±0.76^{abc}	–
Leaves, g/tree	0.24 ±0.03^{c}	2.02 ±1.04^{a}	1.02 ±0.52^{abc}	1.93 ±0.01^{bc}	–
Shoots, g/tree	–	0.22 ±0.13^{bc}	0.27 ±0.19^{c}	0.82 ±0.17^{c}	1.39 ±0.40^{c}
Branch, g/tree	2.73 ±0.07^{a}	1.27 ±0.77^{ab}	1.24 ±0.43^{a}	3.53 ±0.39^{ab}	6.33 ±0.38^{a}
Trunk, g/tree	1.19 ±0.19^{b}	0.88 ±0.39^{bc}	0.92 ±0.41^{abc}	2.62 ±1.03^{abc}	3.91 ±0.57^{b}
Roots, g/tree	2.27 ±0.34^{a}	1.19 ±0.50^{abc}	1.19 ±0.52^{ab}	4.33 ±1.50^{a}	5.91 ±0.49^{a}
Total plant, g/tree	6.43 ±0.41	5.70 ±2.63	5.06 ±0.75	16.07 ±1.10	17.54 ±0.06
Orchard, kg/ha	10.70 ±0.7	9.50 ±4.4	8.40 ±1.2	26.80 ±1.8	29.20 ±0.1

± represents standard deviation
Numbers within sampling dates followed by the same letter are not different at p = 0.05.

mer transfer of P from storage organs to new spring growth, fruits, and new tops. This further confirms that P requirements of early growth originate from P absorbed and stored in the cortex and xylem during the previous year.

Total annual net P accumulation in this established apple tree orchard with a yield of 48 t/ha amounted to 28.7 kg/ha, in which 18.4 kg/ha was accumulated from July 30 to September 21; 10.3 kg/ha was taken up from September 21 to January 15. Two distinct periods of plant P demand were identified, the first beginning in early August to support fruit expansion, the second in mid-September after fruit harvest to replenish P reserves in all plant storage organs. Initial P demand resulting from new leaf and branch growth depends on sources stored over the previous season.

Although it is difficult to quantify the fertilizer recommendation for apple orchards by soil testing at present, it is recommended to construct and monitor the P balance in order to properly compensate for annual apple harvests and the amount of P removed by fruits and leaves. Considering a P fertilizer use efficiency of 25% (Lou, 1998), the initial recommendation for P application required to offset P removal within the orchard would be 115 kg P/ha without considering P supplied from soil. Results from this study indicate that approximately 69 kg P/ha (60%) should be applied basally in the autumn after fruit harvest and the remaining 46 kg P/ha (40%) should be applied prior to fruit expansion in early July. BC

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References

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Grassi, et al. 2003. Tree Physiology, 23:1061.

Lou, R., 1998. Soil-Plant Nutrition, Principle and Fertilization, p. 199.

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Conversion Factors for U.S. System and Metric Units

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.

Other Useful Conversion Factors

Phosphorus (P) x 2.29 = P_2O_5 P_2O_5 x 0.437 = P

Potassium (K) x 1.2 = K_2O K_2O x 0.830 = K

parts per million (ppm) x 2 = pounds per acre (lb/A)

Corn (maize) grain — bu/A x 0.0629 = t/ha

Wheat or Soybeans — bu/A x 0.0674 = t/ha