

## The Effects of Cropping on Uptake, Contents, and Distribution of Nutrients in Apple Trees.

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### Summary

The uptake, distribution and concentrations of nutrients are compared in experiments with bearing and non-bearing specimens chiefly of Golden Delicious and Graasten.

Uptakes of nitrate, phosphorus, calcium and magnesium are higher in trees without fruit, due mainly to high consumption in roots and leaves, while the uptake of potassium tends to be higher in fruit-bearing specimens due to the high consumption of potassium by the fruits.

Leaves from cropping trees or branches contain a higher percentage of nitrogen and calcium, but a lower percentage of potassium than do those from defruited trees. In the cases of phosphorus and magnesium there appeared to be no unequivocal relation. For potassium and calcium the above relationship also applies to other organs than leaves, and there is a distinct residual effect of accumulation one year upon the percentage of the spur leaves next year, which in biennial bearing trees may be dominating over the effect of the present year's cropping. Differences in leaf size do not explain the differences in the nutrient percentages of leaves from bearing and non-bearing specimens, when we exclude the very earliest development stages of the leaves.

The possible reasons for differences in uptake, distribution and concentrations of nutrients are discussed.

### Introduction

In order to improve the understanding of the processes on which is based the development of fruit in apple trees and its relation to the develop-

ment of other parts of the tree, a number of studies have been made in recent years concerning the effects of fruiting on growth, distribution of assimilates, etc. (Hansen 1967 etc., Hansen 1970, 1971). This complex problem also includes relationships between the uptake and distribution in the tree of minerals, and the growth and developmental stage of the tree. The present report presents the results of a pot experiment with trees with and without fruit, as well as of a number of analyses of leaf samples taken from various field experiments.

### Material and methods

Comparisons of leaf samples from trees in different fruit-bearing conditions are based on field experiments as follows:

*A.* Ingrid Marie and Belle de Boskoop, planted 1952. Kept in condition of biennial bearing. Leaves taken from the middle of current year's shoots from specimens with and without fruit.

*B.* Biennial bearing Graasten (Gravenstein), planted 1951.

*C.* Golden Delicious, planted 1958. Leaves from fruit-bearing specimens compared to leaves from trees defruited 14/6, 1963; 28/6 1964; and 25/6 1966, respectively. In 1965 leaves from fruit-bearing and non-bearing spurs were taken at random from fruit-bearing trees.

*D.* Golden Delicious, planted 1961; specimens with fruit as well as deblossomed specimens.

Materials B-D were used and have been described in detail previously (Hansen 1970). Sampling dates may be found in Table 8.

*E. Pot experiment with Golden Delicious.* The material used in this experiment was described previously (Hansen 1970, 1971). Four-years-old trees in 50 litres plastic pots with drainpipes at the bottom and planted in sand + peralite were grown in 1966 in comparable batches of fruiting and defruited trees. Of these two batches, in 1967 some were grown with and a corresponding number without fruit. Leaf samples were taken during the course of the growth season and samples of the various organs of the tree were taken in the autumns of 1966 and 1967, as described previously.

*Technique for watering with and sampling of nutrient solutions.* In 1966 batches of 3 or 4 pots were connected by tubes to a container buried in the ground. The amount of water in the containers was kept at approximately 40 litres, the water capacity per pot being about 10 litres. From the container each pot was watered with 4-8 litres daily, excess water returning to the container. The experiment comprised a total of 14 trees with and 14 without fruit.

When renewing the nutrient solution the pots were washed through with rainwater, and the containers were emptied and refilled with 40 litres of fresh nutrient solution. After being left to drip off for 75-90 minutes the pots were watered 8 times at c. 15 minutes intervals, each time with 4 litres of nutrient solution, excess running back into the central container. This provided a good levelling of concentration. Samples were then taken for analysis. Similarly, before the old nutrient solution was discarded at the end of the period, a sample was taken for analysis after saturation of the pots, adjusting of the water level in the central container, and levelling of the concentration.

In 1967 the same procedure was used, except that each of the 12 pots had its individual nutrient solution container, and the daily watering amounted to 8-12 litres.

The approximate initial concentrations after the addition of fresh nutrients and mixing was 19 milliequivalents/litre for  $\text{NO}_3^-$  and  $\text{Ca}^{++}$  (but until 4/8 1966, only 11), 8 for  $\text{H}_2\text{PO}_4^-$  (but until 18/8 1966, only 6), 8 for  $\text{K}^+$  (but until 27/7 1966, only 4), and 5 for  $\text{Mg}^{++}$ . In addition, micro-nutrients were added (Hansen 1966 a). Following a minor supply of nutrients about the middle of May, watering with nutrient solution was maintained each year from the beginning of

June until well into October. In 1966 the nutrient solutions were renewed every week, in 1967 every 2-3 weeks.

The technique was checked by simultaneous treatment of blank control pots. Pots and containers were protected against light to prevent algal growth.

#### Analysis

All samples were dried at 80°C. Nitrogen was determined in the ground material by micro-Kjeldahl; potassium was determined by flame photometry in a 0.3 normal nitric acid extract of the ash; in the same extract calcium and magnesium were determined complexometrically or by atomic absorption measurements, and phosphorus colorimetrically by the vanado-molybdate method.

### Results

#### I. Nutrient uptake in the pot experiment

In early summer there is a steep increase in the uptake of nitrate and phosphate (Figure 1, Table 1) which is nearly identical for the two batches of trees. The uptake in non-fruiting trees (N) continues to be high throughout July and August, while in the case of trees with fruit (F) the uptake decreases over the same period; in the case of phosphorus this takes place predominantly in August. In September there is a decrease in the uptake of the non-fruiting specimens as well, but both in the late summer and autumn the uptake of the latter remains more than twice as high as in the F-trees.

Table 1. Average decreases in the concentrations of nitrate and phosphorus in the nutrient solution ( $\mu$  equiv./litre) per 24 hrs. and per tree over three periods during 1967

Golden Delicious, experiment E.					
Period		$\text{NO}_3^-$		P	
		F <sub>66</sub>	N <sub>66</sub>	F <sub>66</sub>	N <sub>66</sub>
1/6-9/6	F <sub>67</sub>		463	188	60
	N <sub>67</sub>		825	222	177
12/8-21/8	F <sub>67</sub>	247	389	62	215
	N <sub>67</sub>	932	1281	505	633
2/9-12/9	F <sub>67</sub>	114	271	—59	273
	N <sub>67</sub>	685	1211	535	606

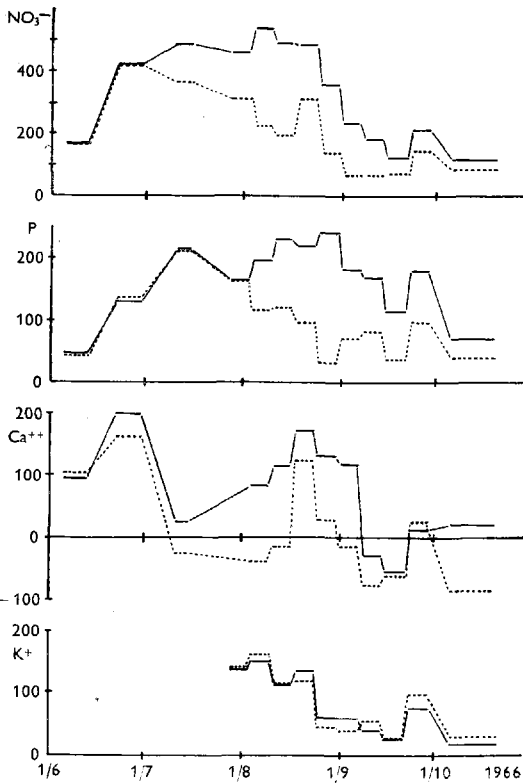


Figure 1. The average decrease in concentration of the nutrient solutions (expressed in  $\mu$  equiv. per litre per 24 hrs. per tree) in 1966 over different periods (indicated by horizontal lines) for bearing (dotted) and non-bearing trees. Golden Delicious, experiment E.

Similarly, the uptake of calcium during July-September is higher in the N-trees. In the case of calcium the curve shows considerable fluctuations

with time, and in some cases the calcium concentration appears to have increased between additions. However, this may be due to systematic errors in the supplying and mixing techniques, e.g., minor quantities of  $\text{CaSO}_4$  may have been precipitated, and later redissolved. However, all trees received identical treatment, and consequently the difference between N-trees and F-trees within each period may be considered significant.

The values for the total content per tree (excluding the rootstock stem) based on the dry matter content and the mineral concentration in the various organs following harvesting of the trees in the autumn also show for nitrogen, phosphorus and calcium the highest uptake in the N-trees (Table 3). This appears to be the case also for magnesium, although it was not clearly demonstrated by the analyses of the nutrient solutions; possibly the technique was too crude to allow sufficient accuracy in the measurements of the relatively small amounts of magnesium. In the case of potassium, on the other hand, the tree analyses indicate that the uptake is higher in the

Table 2. Water supplied (litre per tree) 3/8-31/8 1966 in four comparable batches of trees with (F) and without (N) fruit, respectively

Golden Delicious, experiment E.	
F	N
86.7	68.3
74.3	60.3
82.5	64.3
72.8	61.5
Av.	79.1
	63.6

Table 3. Total content and for 1967 calculated uptake of nutrients (total content autumn 1967 minus content in perennial parts autumn 1966) per tree in trees with (F) and without (N) fruit.  $F_{66}$  and  $N_{66}$  refer to specimens respectively with and without fruit in 1966. The rootstock stem was not analyzed

	Golden Delicious, experiment E											
	dry matter		nitrogen		phosphorus		potassium		calcium		magnesium	
	N	F	N	F	N	F	N	F	N	F	N	F
total, g/tree												
1966	2476	2828	32.9	23.9	6.89	4.49	16.2	19.6	18.4	14.7	2.68	2.28
1967, $F_{66}$	4349	4941	56.7	35.4	9.30	6.36	33.5	37.9	34.2	24.9	5.61	3.56
1967, $N_{66}$	6459	6535	78.9	50.6	12.84	9.57	49.5	48.4	44.6	30.5	8.00	5.09
uptake 1967, g/tree												
$F_{66}$	46.6	25.3	7.30	4.36	29.3	33.7	25.0	15.7	4.62	2.57		
$N_{66}$	54.7	26.4	8.08	4.81	40.0	38.9	30.9	16.8	6.07	3.16		

F-trees, but the difference here is comparatively smaller, nor can it be demonstrated by analysis of the nutrient solutions. In 1967 the uptake was greater by the more vigorous  $N_{66}$ -trees (trees not bearing fruit in 1966) than by the  $F_{66}$ -trees (Table 1,3).

Some measurements of the pH of the nutrient solutions during the period 18/8-14/9, 1966, showed a significant difference in the pH-increase, i.e., in the case of the F-trees the increase was 0.36 units of pH (from pH 5.3), in that of the N-trees 1.23 units (from pH 6.2), from the addition of fresh nutrient solution until 6 days later. The consumption of water was greater in the case of the F-trees (Table 2).

## II. Distribution of nutrients in different organs

The difference demonstrated above in the uptake of nutrients by trees with and without fruit may

in part be due to differences in additional growth in organs at different mineral levels, and in part to differences in mineral concentrations in the individual organs of the two batches of trees. According to Figure 2 and Tables 4 and 7 the former cause was usually predominant.

The somewhat greater uptake of nitrogen, phosphorus, calcium, and magnesium by trees without fruit is caused mainly by the greater new additional growth (*Hansen 1971*) and hence greater uptake by the permanent parts of the tree, in particular the roots; for phosphorus, nitrogen and magnesium also to some degree by new developed leaves (Figure 2). In fruit-bearing specimens the bulk of growth takes place in the fruit at a lower concentration of the minerals in question, this in particular is the case for calcium. Opposite consumption of potassium by the fruits of the bearing trees is high and sufficient to

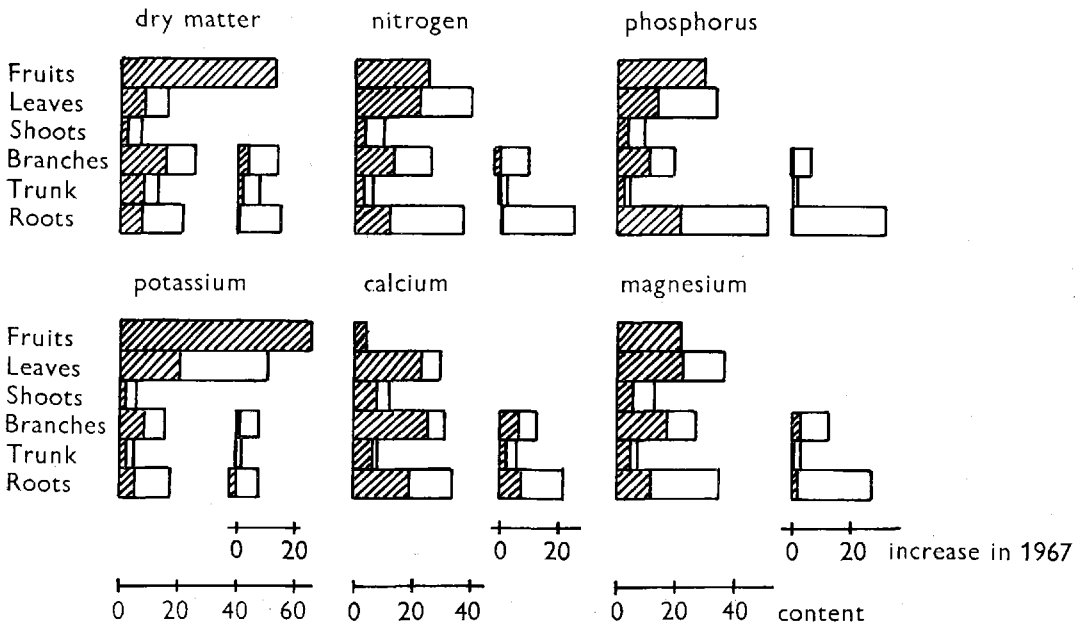


Figure 2. Distribution of nutrients on various organs. Content in bearing trees (hatched) and additional content in non-bearing specimens in the autumn, expressed in per cent. of the average total content per tree (e.g., for nitrogen 28.4 g. in 1966, 46.1 g. for  $F_{66}$  in 1967, 64.8 g. for  $N_{66}$  in 1967, cf. Table 3), average values of the three batches. Increase and additional

increase for branches, trunk and root in 1967 calculated in the same units on the basis of content in the organ in question in the autumn of 1967 minus content in the corresponding organ in the autumn of 1966 (average of the two lots in 1967). The rootstock stem was not included in the analyses. Golden Delicious, experiment E.

Table 4. Nutrient concentrations in various organs of bearing (F) and non-bearing (N) trees. Average values of three batches of trees (1966, F<sub>66</sub> in 1967, N<sub>66</sub> in 1967). Per cent. of dry matter

		Golden Delicious, experiment E					
		potassium		calcium		magnesium	
		F	N	F	N	F	N
spur leaves	Aug.	1.70	1.98	1.53	1.37	0.228	0.273
» »	Sept.	1.83	2.05	1.61	1.33	0.206	0.246
» »	Oct.	1.70	2.32	1.96	1.53	0.251	0.246
leaves of cur. year's shoots	Oct.	1.83	2.32	1.53	1.00	0.251	0.209
current year's shoots	»	0.57	0.69	1.80	1.16	0.197	0.192
spurs	»	0.70	0.77	2.05	1.78	0.213	0.216
branches	»	0.39	0.44	0.96	0.70	0.102	0.098
bark (trunk)	»	0.74	0.91	2.33	1.99	0.171	0.179
wood (trunk)	»	0.14	0.18	0.16	0.12	0.034	0.031
root	»	0.49	0.58	1.51	0.97	0.142	0.156
fruit	»	0.92		0.050		0.040	

counteract the additional uptake of potassium in particular in leaves of the non-bearing trees. It should be emphasized that with the exception of calcium there was no increase, but rather a small reduction, in the amount of any nutrient in 1967 in either root, trunk or branches of the fruit-bearing trees. Accordingly, new additional growth in these parts was exceedingly slight (Hansen 1971).

### III. Concentrations of nutrients in the different organs of the tree

Results of analyses of different organs from the pot experiment may be found in Tables 4-7. Table 8 relates the nutrient contents of the leaves to the fruit-bearing condition of the tree on the basis of leaf samples from the different experiments (A-E). Only samples taken in July or later in the season were included.

Table 5. Percentages of potassium and calcium in various organs in 1967 in trees uniformly treated in 1967, but with (F<sub>66</sub>) and without (N<sub>66</sub>) fruit in 1966.

		Golden Delicious, experiments E.			
		potassium		calcium	
		F <sub>66</sub>	N <sub>66</sub>	F <sub>66</sub>	N <sub>66</sub>
spur leaves,	Aug.	1.81	2.17	1.51	1.40
» » ,	Sept.	1.85	2.12	1.63	1.17
» » ,	Oct.	1.90	2.58	1.95	1.48
leaves of cur. year's shoots,	Oct.	2.05	2.59	1.54	1.01
current year's shoots,	»	0.58	0.69	1.82	1.13
spurs,	»	0.72	0.81	2.12	1.83
branches,	»	0.30	0.43	0.98	0.71
bark (trunk),	»	0.75	0.86	2.50	2.14
wood (trunk),	»	0.15	0.18	0.18	0.13
root,	»	0.38	0.49	1.62	0.95
fruit,	»	0.93	0.90	0.046	0.030

Table 6. Concentration of nutrients in flowers and spur leaves on 16th May 1967 in trees respectively without (N<sub>66</sub>) and with (F<sub>66</sub>) fruit in 1966

		Golden Delicious, experiment E				
		per cent of dry matter				
		nitrogen	phosphorus	potassium	calcium	magnesium
flowers	N <sub>66</sub>	3.34	0.48	2.07	0.45	0.321
»	F <sub>66</sub>	3.13	0.47	1.97	0.62	0.308
spur leaves	N <sub>66</sub>	4.02	0.53	2.22	0.45	0.214
» »	F <sub>66</sub>	3.50	0.46	1.96	0.58	0.190

Table 7. Percentages of nitrogen and of phosphorus in various organs in 1966 and in 1967 in relation to the fruit-bearing condition of the tree. F: with fruit, N: no fruit

		Golden Delicious, experiment E											
		nitrogen				phosphorus							
		1966		1967		1966		1967					
Treatm.	Year	F	N	F	N	F	N	F	N				
Treatm. 1966	.....	F	N	F	N	F	N	F	N				
Treatm. 1967	.....			F	N	F	N	F	N				
spur leaves	..... Aug.	2.64	2.44	2.98	2.59	2.85	2.56	.301	.307	.233	.259	.272	.226
» »	..... Sept.	2.71	2.76	2.75	2.64	2.80	2.41	.397	.579	.260	.328	.333	.276
» »	..... Oct.	2.36	2.31	2.56	2.68	2.68	2.45	.338	.584	.233	.364	.340	.261
leav. of cur. y.'s sh.	»	2.60	2.35	2.81	2.61	2.93	2.63	.340	.546	.243	.352	.329	.284
cur. year's shoot	»	1.47	1.86	1.22	1.46	1.29	1.36	.254	.305	.207	.236	.223	.223
spurs	»	2.18	2.74	1.66	2.04	1.80	2.14	.357	.420	.280	.335	.287	.330
branches	»	0.94	1.20	0.75	0.95	0.83	0.89	.134	.157	.108	.122	.128	.119
bark	»	1.12	1.61	0.79	1.21	1.00	1.09	.153	.209	.090	.131	.125	.123
wood	»	0.36	0.43	0.25	0.30	0.29	0.27	.045	0.053	.039	.042	.044	.041
root	»	1.62	1.90	1.50	1.79	1.71	1.63	.470	.517	.554	.414	.517	.391
fruit	»	0.56		0.46		0.41		.126		.094		.096	

According to Table 4 the K-percentages in the different organs are higher in non-bearing trees, while the reverse is the case for Ca. Similar phenomena may be observed in leaf samples in Table 8, when considering spur leaves from trees in which the differences in fruit-bearing were established within the year in question by defruiting some of the specimens (c), or in the case of leaves from current year's shoots (b). The latter develop

during the course of the summer and may hence be assumed to be particularly susceptible to differences in current fruit development. On the other hand, the K-percentages in spur leaves of biennial bearing trees (d) are higher in bearing trees, and the Ca-percentages in non-bearing trees. This is probably related to the distinct residual effect observed in the pot experiment for K and Ca (Tables 5 and 6). The K-percentages

Table 8. Average values and standard deviation (s) for differences calculated on the basis of content (per cent. of dry matter) in leaves from fruit-bearing trees minus content in leaves of corresponding trees or branches with few or no fruits

- a) all 45 sets of samples.
- b) 18 sample sets of leaves of current year's shoots from the following samplings: Golden Delicious, mat. E. Oct. 1966, 16/8 and Oct. 1967; mat. C, 22/7, 7/10 1963, 24/9 1964; mat. D, 1/9 1967; Gold. Del. and Ingrid Marie, mat. D., 25/9 1964, 15/9 1965; Graasten, mat. B, 4/8, 23/10 1963, 11/8, 16/10 1964; Ingrid Marie and Belle de Boskoop, mat. A, 1/9 1967.
- c) 15 sample sets of spur leaves from Golden Delicious, mat. E, 8/8, 6/9 and Oct. 1966; 16/8, 11/9, Oct. 1967; mat. C, 20/7, 18/8 1965; 11/7, 3/8, 30/8, 22/9 1966.
- d) 12 sample sets of spur leaves from biennial bearing trees, Graasten mat. B, 4/8 1963, 2/7, 4/8, 7/9, 14/10 1964, 20/7, 18/8 1965, 12/7, 4/8, 31/8 1966; Ingrid Marie and Belle de Boskoop, mat. A, 1/9 1967.
- e) level (per cent. of dry matter) of nutrient content of leaves sampled.
- \*) average difference deviating significantly from 0.

	nitrogen		phosphorus		potassium		calcium		magnesium	
	av.	s	av.	s	av.	s	av.	s	av.	s
a	+0.26*	0.29	-0.01	0.07	-0.13	0.26	+0.09	0.34	-0.01*	0.03
b	+0.27*	0.16	-0.01	0.06	-0.19*	0.18	+0.24*	0.22	+0.01	0.02
c	+0.09	0.19	-0.03	0.09	-0.28*	0.23	+0.20*	0.35	-0.03*	0.03
d	+0.43*	0.43	+0.03*	0.02	+0.17*	0.10	-0.28*	0.16	-0.03*	0.02
e	2.1-2.7		0.14-0.35		1.3-2.2		0.8-2.0		0.16-0.30	

are not only higher for the  $N_{66}$ -trees in 1966, but also, particularly in the leaves, for these specimens in 1967, whereas conversely, the  $F_{66}$ -trees show the highest Ca-percentages both in 1966 and 1967, in these cases including fruits. In the case of biennial bearing trees, in any given year the fruit-bearing trees will have had but few fruits in the previous year and hence the possibility of a considerable accumulation of potassium. The spur leaves which develop early may be particularly effected by this and consequently acquire a high percentage of potassium. The reverse will be the case for Ca.

For magnesium the reactions are not unequivocal. The reactions for nitrogen and phosphorus in the different organs of the tree are different for the three batches of trees in Table 7. In 1966 the N-percentages are higher in the non-bearing specimens, with the exception of spur leaves in June (2.94 and 2.60 per cent. for bearing and non-bearing specimens, respectively) and in August, and of leaves on current year's shoots (October). This applies also in general to the remainder of the leaf samples taken (Table 8). In the  $F_{66}$ -trees in 1967 the excess concentration in the non-bearing specimens appears to be reduced also in other organs (Table 7), and in the  $N_{66}$ -trees in 1967 the N-percentage in leaves and roots is now clearly higher in the bearing specimens; only in the woody parts does the N-percentage remain slightly higher in non-bearing than in bearing trees. From 1966 to 1967 there is a general increase in the N-percentage for the leaves, while a reduction

in the remaining parts is most pronounced in the  $N_{66}$ -trees.

As in the case of nitrogen, the P-percentages in the pot experiment in Table 7 in 1966 are also higher in the trees without fruit, in this case in all organs, and often with considerable differences. Otherwise there is a change similar to that for nitrogen when we consider the two batches in 1967, i.e., an increasing tendency towards higher percentages in the trees with fruit. Here, however, it is evident first in the roots, and subsequently in the leaves. Particularly in the  $N_{66}$ -trees the level is generally decreasing from 1966 to 1967.

In accordance with these different reactions for the P-percentages, no general difference has been found on the basis of the total leaf material (Table 8), but the size of the standard deviation here shows that considerable differences - positive or negative - in P-concentration in leaves of trees with and without fruit may occur in individual cases.

The spur leaves may be considerably larger on non-bearing trees than on fruit-bearing ones (*Hansen 1966 b*). Consequently leaf samples in 1965-66 were also analysed after being divided into categories according to size. However, for fully developed leaves this way of comparison produced no significant change in the difference between leaves from bearing and non-bearing spurs, as indicated by the average values given in Table 9. Only at the stage of rapid leaf development, the rate of which may be different for the two batches of trees (*Hansen 1966 b*), the two

Table 9. Difference in nutrient percentage (F-N) between leaves from spurs with (F) and without (N) fruit by comparing respectively

- a) the average percentage of the total leaf mass per sample,  
 b) the percentage of leaves with the same size (see mats B and C). July-Sept. represent average values of 6 sampling dates, i.e., 20/7 and 18/8 1965, plus 4 samplings between 21/6 and 22/9 1966.

Experiments B and C.

	nitrogen		phosphorus		potassium		calcium		magnesium	
	a	b	a	b	a	b	a	b	a	b
Graast. 26/5 65 . . . .	+0.12	+0.73	-0.003	+0.047	+0.42	+0.36	+0.38	-0.10	+0.042	-0.024
» 10/6 65 . . . .	+0.67	+0.56	+0.056	+0.038	+0.41	+0.40	+0.04	-0.23	+0.007	-0.008
Graast. July-Sept. . .	+0.17	+0.21	+0.021	+0.018	+0.27	+0.23	-0.28	-0.40	-0.037	-0.053
Gold. Del. »	-0.01	+0.01	0.000	0.000	-0.17	-0.17	+0.06	+0.08	-0.027	-0.027

different ways of comparing may give different results, as observed for the sampling of 26/5 in Table 9.

### Discussion

Whereas the total uptake of nutrients by a plant will normally depend on growth (size of plant) and availability of nutrients, we here observe a third considerable factor, i.e., the distribution of growth on the different organs, which determines to a great extent the total uptake by the tree of a certain nutrient, and its seasonal variations. The uptake of nitrogen and phosphorus is related to the vegetative growth (*Poulsen & Jensen 1964, Hansen 1968*), in the autumn in particular to the growth of the roots (*Mochizuki & Kamakura 1968*). The very high consumption of potassium (*Quinlan 1969*) but very low consumption of calcium by the fruits also influences the total uptake by the tree. Probably the high K-consumption in the fruits may also explain the fact that the fruit yield in previous fertilizer experiments (*Dullum and Dalbro 1956, Greenham 1965*) proved to be affected in particular by the potassium supply. Also, high potassium levels enhance the tendency to biennial bearing by increasing the yield in »on« years, thus accelerating the rhythm (*Ljones 1951*).

As shown above, the influence of the distribution of growth on the uptake of nutrients also causes changes in the pH values of the nutrient solutions. The steeper pH-increase in the case of non-bearing trees may have been due to the particularly high uptake of anions (nitrate, phosphate) here compared to the uptake of cations, resulting in the release of  $\text{HCO}_3^-$ -ions by the roots exceeding that of  $\text{H}^+$ .

The greater consumption of water by the fruit-bearing trees may be due not only to production of fruits of a high water content, but may to an even greater extent be caused by a higher transpiration intensity, since furthermore the leaf area is smaller for the bearing specimens (*Hansen 1971*). Hence this follows the photosynthetic intensity which has also been found to be higher in the case of bearing trees (*Hansen 1970 f*). Preliminary studies suggest that this is related to a higher degree of opening of the stomata.

The concentration of nutrients in individual organs may also be affected by the condition of fruit-bearing within certain limits. As reported by *Bould (1966)*, and as shown in other studies (*Ljones 1951, 1954, Ljones and Braadlie 1954, Gruppe 1954, Weeks et al. 1958, Hansen 1965, Ktosowski 1967*), the leaves of trees with fruit have a higher concentration of nitrogen, and often also of calcium and magnesium, but a lower percentage of potassium (in most cases leaves from current year's shoots were used for comparison). For phosphorus the results, as shown here also, are not unequivocal, and deviations from the above norm may occur for the other elements (*Emmert 1954, Ljones 1954, Mason 1955, Hansen 1965*). In the case of potassium the discrepancies may be due to the fact, that at low potassium levels indistinct differences between the leaves of bearing and non-bearing trees may occur (*Ljones 1954*), or - as for calcium - to the fact that in the case of biennial bearing trees the residual effect from the previous year and a direct effect from the current year are counteracting each other. Occasionally the higher potassium content in the leaves of the non-bearing trees does not manifest itself until late in the season (*Mochizuki 1962*), possibly after having been higher in the leaves of the bearing trees at the beginning of the season (biennial bearing prune; *Davis 1934*).

The relations between potassium or calcium concentration and condition of fruit-bearing may possibly be explained by consumption by the fruits being high and low, respectively. As the difference between the total amounts of new growth in the two types of trees may be small (*Hansen 1971*), the availability to the other organs of the tree is probably affected, causing a decrease and increase in the K- and Ca-percentages, respectively. Similar explanations of the potassium relations have been proposed by *Lilleland and Brown (1938), Cain and Boynton (1948), Popenoe and Scott (1956), Weeks et al. (1958) and Sato (1961)*.

The percentage or distribution of nitrogen in other organs than leaves, e.g. spurs, buds, shoots or roots may be affected in different ways (*Davis 1931, Harley et al. 1942, Kato and Ito 1962, Sa-*



*hulka* 1962, *Feucht* 1965, 1966, 1967), although frequently the concentration was found to be highest in the fruit-bearing specimens (*Hooker* 1920, *Kraybill* et al. 1925, *Bielinska* 1956, *Mochizuki* 1962, *Dzieciot* and *Bielinska-Czarnecka* 1962, *Bielinska-Czarnecka* et al. 1964, 1966, *Kazaryan* and *Arutyunyan* 1966). This agrees with the varying results obtained for N and P in the present study, where there was a shift from a generally higher percentage in the non-bearing trees in 1966 (except N-pct. of leaves) towards a lower percentage in 1967, in particular for  $N_{66}$ -trees, i.e., with increase in tree size, growth and total nutrient requirement. This shift may be explained by a change in the conditions for nutrient uptake: a) by unrestricted uptake of nitrogen and phosphorus and a high availability of assimilates for vegetative growth the formation of vigorous tissues of a high N- and P-percentage may be induced (1966), b) by beginning limitations for the uptake of nitrogen and phosphorus a relative deficiency will first turn up for the larger, non-fruiting trees of the greater nutrient demand ( $N_{66}/N_{67}$  in 1967), resulting in a reduced percentage compared to the fruiting trees of lower total nutrient demand (but with equal supply). For nitrogen this will first - and normally - be seen in the leaves, for phosphorus in the strongly P- consuming roots.

The residual effects from differences in accumulation of reserves become manifest in the next spring (Table 6). For nitrogen this is frequently obliterated quite rapidly in the following spring (*Mochizuki* 1962, *Hansen* 1968), whereas in spur leaves the differences for potassium and calcium may be maintained throughout the summer. The residual effect in leaves is evidence of a retransportation from older to new young tissues, even in the case of calcium which is often considered rather immobile (but see also *Yokomizo* et al. 1964, *Ghosheh* 1962). Yet the residual effect for calcium is clearly preserved also in the perennial parts of the tree which suggests its mobility to be lower than that of potassium.

When evaluating nutrition status by leaf analyses it is important to know factors, other than the nutrient supply, which may affect the content of the leaves. Normally, leaves from the middle

section of current year's shoots are used for this purpose. Table 8 indicates that in the case of bearing specimens, as compared to non-bearing ones, it is necessary to anticipate higher values by 10-15 per cent. in the case of nitrogen, and 12-25 per cent. for calcium, but lower by 10-15 per cent. in the case of potassium. However, the difference may vary considerably in value, probably depending on the amount of fruit.

### Oversigt

*Frugtmængdens indflydelse på mineralstofoptagelse, -indhold og fordeling hos æbletræer*

Næringsstofoptagelse, -fordeling og -koncentrationer sammenlignes i et karforsøg med bærende og ikke-bærende Golden Delicious, ligesom næringsstofprocenterne i blade er sammenlignet hos træer med mange og med få eller ingen frugter i forskellige markforsøg, især med Golden Delicious og Graasten.

Nitrat-, fosfor-, calcium- og magnesiumoptagelsen er størst hos træer uden frugt, især på grund af stort forbrug i rødder og blade, mens kaliumoptagelsen tenderer mod at være størst hos træer med frugt, p.g.a. et stort kaliumforbrug hos frugten.

Bladene hos træer eller grene med mange frugter har en højere kvælstof- og calciumprocent, men en lavere kaliumprocent end hos træer, hvor frugten er fjernet. For fosfor og magnesium er sammenhængen ikke entydig. For kalium og calcium gælder den samme sammenhæng som for blade også for andre organer, og der er en tydelig efter-effekt efter ophobning i træet et år på sporebladernes procenter næste år. Hos vekselbærende træer kan dette overskygge den direkte effekt af det indeværende års bæringstilstand. Forskel i bladstørrelse er kun i bladenes tidligste udviklingsfaser af betydning ved vurderingen af forskellen i bladenes næringsstofprocenter hos bærende og ikke-bærende træer.

Årsagerne til forskelle i næringsstofoptagelse, -fordeling og -koncentrationer diskuteres.

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