State Research Organisation for Plant Culture **Report No. 1207**

State Research Station Blangstedgaard (E. Poulsen)

The Effect of Carbon Dioxide Concentration on the Early Growth of Apple Trees

Poul Hansen

Abstract

Three-year-old 'Spartan' and two-year-old trees of rootstock type 'M 7 A' (*Malus x domestica*) were placed in growth chambers before bud break and then exposed to concentrations of c. 100, 325 and at least 1200 ppm CO_2, respectively.

New growth (leaves and shoots) during 2-3 weeks following bud break was only slightly affected by differences in CO_2-concentration, but later there was a distinct effect. This indicates that a shift from reserves to current photosynthesis as major basis for growth takes place soon after bud break.

Oversigt

Tre-årige 'Spartan' og to-årige grundstammer 'M 7 A' blev kort før knopbrydning anbragt i vækstkamre og derpå behandlet ved henholdsvis ca. 100, 325 og mindst 1200 ppm CO_2.

Nyvæksten (blade og skud) i de første 2-3 uger efter løvspring var kun i mindre grad påvirket af forskelle i CO_2-koncentratioon, men derefter steg tilvæksten tydeligt med stigende CO_2-koncentration. Dette tyder på, at den løbende fotosyntese hurtigt bliver det væsentlige grundlag for væksten.

Introduction

Reserves in apple trees seem to be of particular importance in the very earliest phases of growth; subsequently current photosynthesis yields the dominating part of building materials for growth (*Hansen* 1971, *Hansen* and *Grauslund* 1973). Under these circumstances, the new growth of apple trees shortly after bud break should be dependent upon such differences in carbon dioxide concentration, which normally affect the rate of photosynthesis. To elucidate this question the early growth of apple trees was followed at three levels of CO_2.

Material and methods

Three growth chambers, ground area 12.4 m^2, height 2.5 m, with walls of double plastic and built in a green house, were used. Specimens of *Malus x domestica* were moved into the chambers on April 14th, 1972; in each chamber were 8 trees of three-year-old 'Spartan', planted in 15 litres plastic pots in the spring of 1971, and 7 similar pots each containing 3 two-year-old trees of rootstock type 'M 7 A'. Shoots on the rootstocks were cut off 5 cm from the trunk. Only a few buds were green; they were removed.

The chambers remained closed. The treatments were:

A. Low CO_2. The air entering the growth chamber had been passed through NaOH. Powder of $Ca(OH)_2$ was spread on the floor about once a week.

B. Normal CO_2. Supply of ordinary atmospheric air.

C. As B, but every third hour during daylight 100 litres of CO_2 were added.

The air supplied was humidified by passage through rain water. However, the rate of air supply was too low to affect temperature and air composition of chambers efficiently. Therefore, $Ca(OH)_2$ powder was spread to absorb CO_2 in treatment A.

All shoots from the rootstocks and every second new shoot from 'Spartan' were sampled on May 5th. On May 30th the remaining new growth was sampled. The material was dried (80°C) and weighed.

CO_2 was measured in air samples. 500 ml flasks were placed inside the chambers. Next day at 8 or 14 o'clock 10 ml 0.01 N $Ba(OH)_2$ was added and the flask was quickly closed. After at least 16 hours, titration with 0.01 N HCl and cresolphthalein was carried out. Air samples from the outside served as reference (325 ppm CO_2).

Results

Growth conditions

As the amount of air supplied was rather small compared to the volume of the chambers, the temperature during sunny periods increased to 25°-35°C. Daily minimum temperatures usually ranged from 12° to 16°C. Weekly averages were between 18° and 22°C. Temperature differences between the chambers of up to 1°C were detected, but they were not consistent. The relative air humidity at night was about 90 %, during the daytime usually 60-70 %.

Table 1. ppm CO_2. Average of daily samplings

	Treatment		
Period	Low CO_2	Normal CO_2	High CO_2
20. April-4. May	100	480	≥1300
5. Maj-30.May	110	265	≥1200

Carbon dioxide determinations showed a reduction to about 100 ppm CO_2 in treatment A (Table 1), which is probably near the CO_2 compensation point (*Zelitch* 1971). The concentration of CO_2 in treatment C was increased to at least 4 times the normal value, which would probably involve about the maximum rate of photosynthesis as a function of CO_2 concentration (*Madsen* 1971).

Growth

'Spartan'. During the first three weeks the size of individual shoots was clearly increased by increasing CO_2 concentration (Table 2). At the end of the experiment (May 30th) the total amounts of both leaves and woody parts of extension shoots (> 10 cm of length) were greatly reduced at low CO_2 concentration and in-

Table 2. Effect of CO_2 concentration upon growth of leaves and new shoots. 'Spartan'

		Treatment			
Date	New growth	Low CO_2	Normal CO_2	High CO_2	LSD[3]
5. May[1])	g dry mt. in shoots/tree	13.0	15.3	18.0	n.s.
	Number of shoots/tree	79	78	73	n.s.
	mg/shoot	167	197	250	56
30. May	g dry mt./tree	38.8	72.3	86.1	12.0
	g » » in spurs[2])/tree	15.2	18.7	16.0	n.s.
	g » » shoot leaves/tree	16.7	36.7	46.3	6.4
	g » » shoots (wood)/tree	6.9	16.9	23.8	4.1
	Number of shoots/tree	32.0	57.8	65.4	8.6
	cm/shoot	14.7	15.4	15.6	n.s.
	mg wood/cm shoot	14.6	18.9	23.4	2.4

[1]) Every second shoot sampled.
[2]) Terminal growth below 10 cm.
[3]) Least significant difference at 95 % level. (n.s. = not significant).

creased at high CO_2 concentration as compared to »normal«. This was due to an effect upon numbers as well as thickness of shoots.

Rootstocks. During the first three weeks there was no significant difference (Table 3). However, these trees were cut back which resulted in a slower bud break. All leaves were removed on May 5th, this also explain that growth during the period May 5-30th was less affected than in case of 'Spartan'. Nevertheless, leaf mass and shoot length were significantly reduced at low CO_2 concentration and thickness of shoots was increased at high CO_2 concentration.

Grauslund 1973). The reaction to different CO_2 concentrations is still relatively small after the second shoot removal in the rootstocks (Table 3), which indicates an effect of reserves also at that time, when leaves are not present. The above results agree with results from apple seedlings where the corresponding amounts of reserves must be small. In contrast, CO_2 enriched air (2000 ppm) during 4 weeks following germination here increased the height of the plants by more than 50 % compared to air of 400 ppm CO_2 (*Krizek et al* 1971).

The above values of a growth of more than 70 % at low compared to normal CO_2 concentration for the first 2-3 weeks following bud break may be too high to consider as the part of the total growth at normal CO_2 concentration based upon reserves, because photosynthesis at low CO_2 concentration can not be excluded with the present technique.

Table 3. Effect of CO_2 concentration upon growth of leaves and shoots. Rootstock 'M 7 A'

		Treatment			
Date	New growth	Low CO_2	Normal CO_2	High CO_2	LSD
5. May	g dry mt./tree	1.9	1.9	2.3	n.s.
30. May	g dry mt./tree...............	3.2	3.9	4.3	0.9
	g » » leaves/tree	2.2	2.7	2.9	0,4
	g » » shoots (wood)/tree ..	1.0	1.2	1.4	0.2
	Number of shoots/tree	20.6	20.1	21.4	n.s.
	cm/shoot	6.8	8.6	7.9	0.9
	mg wood/cm shoot	6.8	7.0	8.0	0.5

Discussion

The investigations on 'Spartan' were carried out to obtain some information concerning the reactions of an intact tree of a certain size, while on the rootstocks the effects of cutting before bud break and repeated cutting shortly after bud break were included. In all cases the results indicate that less than three weeks after the appearence of green plant parts an effect of CO_2 concentration upon growth rate can be detected. Still, the new growth at low CO_2 concentrations amounts to 72-100 % of the growth with normal or increased CO_2 concentrations in these periods (Tables 2 and 3), compared to around 40 % for the additional growth in 'Spartan' in the period May 5th – May 30th, where leaves were already present (Table 2). Reserves disappear from the old part of the tree during the spring and may account for some of the very early growth (*Hansen* and

When leaves are developed the growth is strongly dependent upon CO_2 concentration, i.e. upon current photosynthesis (*cf. Hansen* 1971, 1972). Experiments with different light intensities also show current photosynthates to be the major contributor to the early growth (*Priestley* 1963, *Tepper* 1967).

References

Hansen, P., 1971: ^{14}C-studies on apple trees. VII. The early seasonal growth in leaves, flowers and shoots as dependent upon current photosynthates and existing reserves. – Physiol. Plant. 25: 469-473.

Hansen, P., 1972: Some effects of ringing, defoliation, sorbitol-spraying, and bending of shoots on the rate of translocation, on accumulation and on growth in apple trees. – Tidsskrift Planteavl 76: 308-315.

– & *Grauslund, J.*, 1973: ^{14}C-studies on apple trees. VIII. The seasonal variation and nature of reserves. – Physiol. Plant 28: 24-32.

Krizek, D. T., Zimmerman, R. H., Kleuter, H. H., & Bailey, W. A., 1971: Growth of crabapple seedlings in controlled environments: Effect of CO_2 level, and time and duration of CO_2 treatment. – J. Amer. Soc. Horot. Sci 96: 285-288.

Madsen, E., 1971. The effect of carbon dioxide concentration on the photosynthetic rate in tomato leaves. – Royal Veterinary and Agricultural University, Yearbook 1971: 195-200.

Priestley, C. A., 1963. The carbohydrate resources of young apple trees under four levels of illumination. – Ann. Bot. 27: 435-446.

Tepper, H. B., 1967. The role of storage products and current photosynthate in the growth of white ash seedlings. – Forest Sci. 13: 319-320.

Zelitch, I., 1971. Photosynthesis, photorespiration, and plant productivity. – N. York & London.

Manuscript received October 30, 1974