SUOMEN METSÄTIETEELLINEN SEURA — FINSKA FORSTSAMFUNDET

ACTA FORESTALIA FENNICA

81

ARBEITEN DER
FORSTWISSENSCHAFTLICHEN GESELLSCHAFT
IN FINNLAND

PUBLICATIONS OF THE
SOCIETY OF FORESTRY
IN FINLAND

PUBLICATIONS DE LA
SOCIÉTÉ FORESTIÈRE
DE FINLANDE

HELSINKI 1967

Suomen Metsätieteellisen Seuran julkaisusarjat:

ACTA FORESTALIA FENNICA. Sisältää etupäässä Suomen metsätaloutta ja sen perusteita käsitteleviä tieteellisiä tutkimuksia. Ilmestyy epäsäännöllisin väliajoin niteinä, joista kukin yleensä käsittää useampia tutkimuksia.

SILVA FENNICA. Sisältää etupäässä Suomen metsätaloutta ja sen perusteita käsitteleviä kirjoitelmia ja lyhyehköjä tutkimuksia. Ilmestyy neljästi vuodessa.

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HELSINKI 1967

Acta Forestalia Fennica 81.

Suomalaisen Kirjallisuuden Kirjapaino Oy Helsinki 1968

TRIALS WITH CARBON DIOXIDE, LIGHT AND GROWTH SUBSTANCES ON FOREST TREE PLANTS

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SELOSTUS:

HIILIDIOKSIDI-, VALO- JA KASVUAINEKOKEITA METSÄPUUNTAIMILLA

HELSINKI 1966

Suomalaisen Kirjallisuuden Kirjapaino Oy Helsinki 1966

The concentration of carbon dioxide, which averages 0.03 % in the atmosphere close to the earth, is known to be an important limiting factor for plant growth when the other growth-promoting conditions are optimal. For this reason, the carbon dioxide level in greenhouses has been artificially increased, and in many cases the plants have ripened earlier and given larger and better-quality yields.

Numerous reports are to be found in the literature dealing with results of CO_2-enrichment trials on horticultural crops as well as practical experiences in many countries (DAUNICHT 1965). Similarly, in Finland investigations have been underway since 1957, and the results obtained thus far have recently been published (HÅRDH 1965a; VOIPIO 1966).

In 1964 trials were begun on the growth-promoting effects of enhanced carbon dioxide levels upon forest tree plants grown in plastic houses. These trials demonstrated that more vigorous growth of spruce, pine and birch seedlings could be achieved when the CO_2 concentration was increased by burning propane to about 0.2 %, or seven times the normal level (HÅRDH 1965b). The enhanced growth was evident in the length of the shoot and the roots as well as in the weight of the plant. In 1965 experiments on the influence of carbon dioxide on grafts, seedlings and cuttings of forest trees were continued in the plastic houses of the Forest Breeding Foundation at Haapastensyrjä near Loppi as well as in controlled conditions in growth chambers of the Institute of Horticulture at Viik. These trials also included the effect of different wavelength of light and growth substances on the plants.

Light is indispensable for plant photosynthesis. However, only the red and blue regions of the spectrum are efficiently utilized by plants in photosynthesis. Therefore, it has been proposed that illumination with a mixture of red and blue light would result in the most efficient utilization of the electrical energy by the growing plants. In recent years special fluorescent lamps have been developed for horticultural use (TL lamps), whose light composition corresponds closely to the peaks of the chlorophyll absorption curve. Among such lamps are the trade names Floralux and Gro-lux.

In 1965 trials were carried out at Viik with cuttings of spruce and birch using Floralux lamps either together with daylight or as the sole source of illumination. The spruce cuttings were of the strains Heinola (E 81) and Urjala (Plusm 10) and the birch cuttings were of Olli-visa (E 1092) from Punkaharju. All the cuttings were one year old and were obtained through the Forest Breeding Foundation. They were planted on January 30, 1965, grown for a 40-day trial period, and measured on March 10. The experimental conditions, treatments and results of this trial are given in Table 2.

Growth substances. Investigators in many countries, among others in Japan, have performed extensive trials on the effect of plant growth regulators on the development and flower formation of coniferous plants. According to SATO (1963), species of the families *Taxodiaceae* and *Cupressaceae* are sensitive to the influence of gibberellic acid, while plants of the families *Juniperaceae* and *Pinaceae* do not show such a distinct response. Treatment with gibberellic acid (GA) at rates of 200—300 ppm accelerated flowering, and the effect was more pronounced when GA was applied together with 1-naphthyl acetic acid (NAA). Treating young plants with 10—200 ppm GA brought about a marked increase in stem elongation of most species.

In connexion with the experiments carried out at Haapastensyrjä in 1965, the plants were treated with both gibberellic acid and a mixture of GA and NAA. The GA was a product of Pfizer (A 3, active ingredient 90 %) while the NAA was a horticultural quality preparation of the firm BDH. These substances were used to treat first- and second-year grafts of pine, seedlings of spruce, pine and birch, as well as cuttings of birch. The methods of treatment, concentrations of the chemicals and results of these trials are presented in Tables 3—5.

Temperature and CO_2 concentration. During the summer of 1965 daily measurements of the maximum and minimum temperature in each of the plastic houses were made, and weekly determinations of the carbon dioxide content were made

Table 1. Maximum and minimum temperatures and CO_2 % in three plastic houses at Loppi. Measurements at 9 o'clock AM.

Date	Check			CO_2 0.2 % at 8—10 and 14—16 o'clock			CO_2 0.2 % at 6—10 o'clock		
	Min. C°	Max. C°	CO_2 %	Min. C°	Max. C°	CO_2 %	Min. C°	Max. C°	CO_2 %
28. 6			.03—.06			.10—.15	15	34	.15—.17
29. 6	9	30	.03—.05	10	35	.14—.20			
30. 6	8	32	.03—.05	8	34	.17—.19			
2. 7	8	30	.03—.05	8	32	.14—.19			
6. 7	4	32	.02—.04	4	34	.16—.20	6	34	.18—.19
14. 7	6	37	.05—.06	5	37	.18—.20	11	30	.23—.26
21. 7	6	39	.02—.04	6	39	.19—.22	9	38	.19—.22
27. 7	9	36	.03—.05	10	36	.18—.23	9	36	.19—.23
5. 8	7	33	.01—.02	8	34	.18—.22	7	32	.18—.21
11. 8	5	36	.03—.05	5	38	.16—.22			
21. 8	2	35	.03—.05	2	37	.18—.22			
26. 8	11	36	.02—.04	11	37	.17—.20			
1. 9	4	38	.04—.05	4	48	.14—.19			

using the Japanese Riken Keiki gas indicator. Table 1 shows the results of these measurements in one check house and in two houses where CO_2 enrichment was carried out by different methods.

It can be seen that the differences between the maximum (daytime) and the minimum (night time) temperature were quite large and furthermore that the burning of propane in the two CO_2-enriched houses did not raise the temperature appreciably above that in the check house. This latter observation was apparently due to the fact that the summer of 1965 was generally cooler than the previous summer, when temperature differences between the plastic houses were often substantial (HÅRDH 1965b). In these experiments, as in previous ones, there were variations in the CO_2 concentration in different parts of the same house and on different days, despite the attempts to maintain the CO_2 level at 0.2 %. This can be attributed to the effect of wind and temperature fluctuations.

Table 2 gives the length of the shoots of spruce and birch cuttings as well the weight of the plants after the 40-day period under controlled conditions at Viik in 1965. It can be seen that both spruce and birch cuttings grew better when the CO_2 concentration was 0.2 % than when it was 0.05 % (I and II). Illumination with red light for 15 hours a day resulted in a slight growth increase as compared with white light for the same period (I and IV), but an especially pronounced increase in growth was achieved when the plants were given continous red light and 15 hours per day white light (I and III). This would indicate that the growth of such plants could be promoted by, for example, even a weak red light of Floralux fluorescent tubes during the night. Gibberellic acid was

Table 2. Mean length of shoot (cm) and weight of cuttings (mg) of spruce and birch grown 40 days under controlled conditions at Viik, 1965. Temperature 35° C (day) and 15° C (night). Three treatments (10 plants in each) with 400 ppm gibberellin (GA) at 10-day intervals.

Treatment	Spruce				Birch			
	Length of shoot cm		Weight of plant mg		Length of shoot cm		Weight of plant mg	
	0	GA	0	GA	0	GA	0	GA
I White light 15 h per day, CO_2 0.05 % ..	2.5	2.4	55	55	7.0	15.1	300	1 070
II White light 15 h per day, CO_2 0.2 %	3.4	3.5	116	80	13.6	19.5	840	1 250
III Red light 24 h + white light 15 h per day, CO_2 0.05 % ..	3.1	3.6	105	109	23.3	25.3	2 070	1 680
IV Red light 15 h per day, CO_2 0.2 %	2.8	3.3	70	124	21.6	32.1	1 700	2 250

of no benefit to spruce but stimulated to some extent the growth of birch. The latter plants were both longer and more sturdy than the untreated birch cuttings.

Trials were carried out at Haapastensyrjä with both large and small first and second-year pine grafts. There were 50 plants per plot and four replicate plots. The first-year material had been grafted between May 31 and June 4, 1965 and the measurements were made on September 2, 1965. Application of carbon dioxide took place daily at the hours 8—10 and 14—16 during the period June 29—September 2. At the end of the trial it was found that the average shoot length in the plastic house with normal CO_2 content was 70.1 mm while in the house with CO_2 enriched to 0.2 % the length was 74.7 mm.

Second-year grafts were treated in the check and the CO_2-enriched house with urea as well as with GA six times and with GA + NAA two times at 10-day intervals. The results (Table 3) show that increasing the CO_2 concentration to 0.1 and 0.2 % produced a marked enhancement in the length of the shoot, in some cases as much as 50 % greater than in the check house. Treatment with urea, gibberellic acid and a mixture of GA + NAA had no appreciable effect on the growth of the plants. The plots which had been treated with a concentrated (600 ppm) dosage of GA as well as with GA + NAA showed a high plant mortality, indicating that high concentrations of growth substances may be injurious to pine grafts. None of these treatments had any effect in stimulating flowering.

The influence of gibberellic acid was also tested on seedlings of pine, spruce and birch in plastic houses containing carbon dioxide levels of 0.03 %, 0.1 % and 0.2 %. The results (Table 4) show that the growth of all three species was stimulated by CO_2 enrichment. The carbon dioxide was applied during four hours a day, either at the hours 6—10 or at 8—10 and 14—16. No

Table 3. Trials with 2nd-year pine grafts at Haapastensyrjä. Measurements made 1. 9. 65, results are means of 200 plants.

Treatment	Check		CO_2 0.2 %	
	Length of shoot, cm	Dead %	Length of shoot, cm	Dead %
Large grafts				
I Unsprayed	19.7	1.2	23.8	3.6
II Urea 0.5 % + Panfix 0.2 %	19.3	2.2	23.4	0
III GA 300 ppm	21.5	8.8	24.0	25.5
IV GA 200 + NAA 200 ppm	21.6	47.7	25.5	11.8
V GA 600 ppm	19.2	54.6	25.7	30.7
Small grafts	Check		CO_2 0.1 %	
I Unsprayed	17.7	0	20.1	0
II Urea 0.5 % + Panfix 0.2 %	16.0	2.9	15.3	2.5
III GA 300 ppm	18.1	1.7	28.6	2.2
IV GA 200 + NAA 200 ppm	15.0	1.7	22.5	47.6
V GA 600 ppm	14.2	28.6	23.5	1.7

Table 4. CO_2 and GA treatment (3 applications) on seedlings of pine, spruce and birch. Measurements made 3—4. 9. 65; results are means of 200 plants.

Applications	Weight of plant g	Length of plant cm	Length of roots cm	Weigt of plant g	Length of plant cm	Length of roots cm
Pine	Check			CO_2 0.2 % at 6—10		
Check	1.62	13.0	16.5	2.05	15.2	17.4
GA 300 ppm	1.00	15.0	14.3	2.33	18.0	15.8
GA 200 »	1.33	15.1	16.0	1.98	20.1	16.6
GA 100 »	1.48	14.4	14.5	1.81	15.4	17.2
Max. length		18.5			28.6	
	CO_2 0.2 % at 8—10, 14—16			CO_2 0.1 % at 8—10, 14—16		
Check	1.81	13.3	19.4	3.08	15.4	19.8
GA 300 ppm	2.65	15.3	15.4	1.57	16.7	15.2
GA 200 »	1.00	17.8	17.3	2.51	17.4	18.2
GA 100 »	1.67	13.5	15.2	2.58	17.0	16.8
Max. length		26.7			24.6	
Spruce	Check			CO_2 0.2 % at 6—10		
Check	0.56	9.9	11.5	0.98	10.5	15.5
GA 300 ppm	0.57	9.6	11.1	0.68	11.6	14.5
GA 200 »	0.71	11.3	13.9	0.80	12.4	14.5
GA 100 »	1.58	11.4	11.7	0.95	12.2	15.0
Max. length		20.[illegible]			21.0	
	CO_2 0.2 % at 8—10, 14—16			CO_2 0.1 % at 8—10, 14—16		
Check	1.25	12.5	15.5	1.43	10.0	16.4
GA 300 ppm	1.69	10.4	13.4	0.60	9.6	14.2
GA 200 »	0.75	12.6	14.8	1.69	11.5	13.1
GA 100 »	0.89	13.2	13.2	0.82	11.6	14.7
Max. length		21.5			18.3	
Birch	Check			CO_2 0.2 % at 6—10		
Check	10.63	49.0	18.9	9.87	62.8	19.9
GA 300 ppm	6.19	47.5	15.0	5.93	40.6	14.1
GA 200 »	7.13	54.0	18.3	3.68	52.3	14.2
GA 100 »	9.28	56.1	18.9	8.34	58.0	19.8
Max. length		89.0			97.6	
	CO_2 0.2 % at 8—10, 14—16			CO_2 0.1 % at 8—10, 14—16		
Check	7.87	61.5	21.3	6.96	64.0	16.3
GA 300 ppm	5.10	41.5	15.3	5.72	46.9	16.8
GA 200 »	5.19	49.6	19.3	6.46	50.1	14.9
GA 100 »	9.30	50.5	18.9	4.39	55.2	15.1
Max. length		98.4			104.9	

Table 5. CO_2 and GA tests on birch cuttings. Planted July 22—23, sprayed two times with GA, measured Sept. 5, 1965.

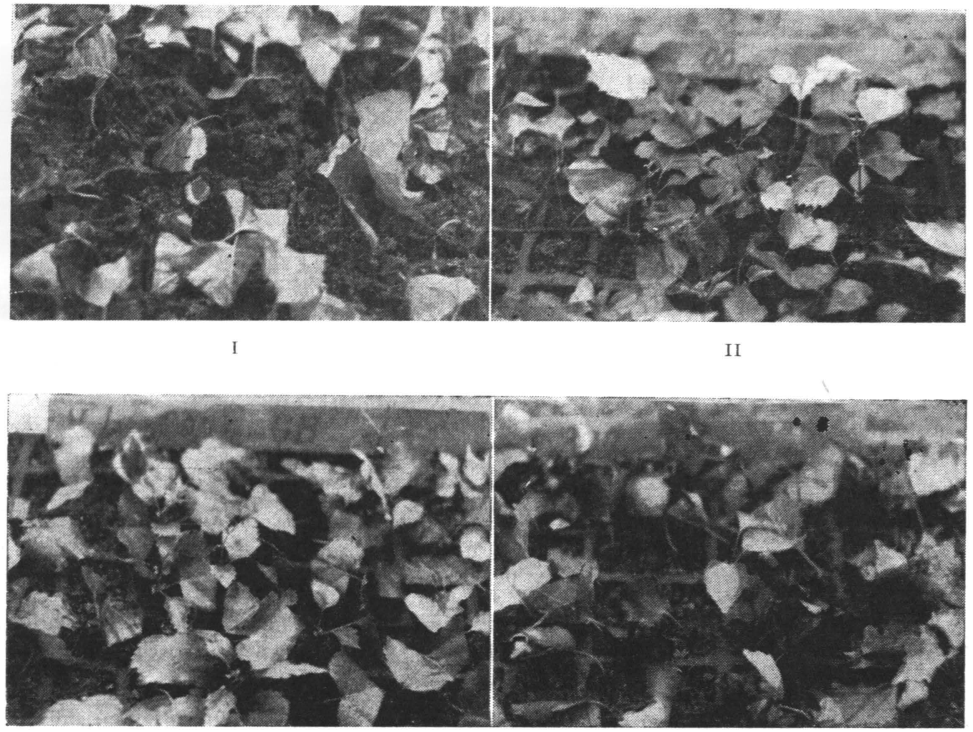
Treatment	Length of plants cm	Rooted %	Length of plants cm	Rooted %
	Check		CO_2 0.2 % at 8—10, 14—16 o'clock	
Check	—	37.4	—	51.1
GA 300 ppm	14.2	29.1	16.5	31.0
GA 200 »	19.1	36.3	20.9	37.4
GA 100 »	14.9	46.0	28.0	53.2

essential differences were seen between the two methods of gas application as regards the length and weight of the plants. Likewise, there were no appreciable differences between CO_2 at the rates of 0.1 and 0.2 %, so the lower rate of 0.1 % appears to be adequate for promoting growth of tree seedlings, as has been established in the case of horticultural crops. Gibberellic acid at 100—200 ppm caused an increase in the length of the pine and spruce seedlings, whereas their weight and sturdiness were usually less than those of the untreated plants. Birch received no benefit from the GA treatments.

Birch c u t t i n g s were treated with gibberellic acid at Loppi, both in normal-air houses and in CO_2-enriched houses (Table 5). At the high CO_2 level both the rate of growth and the rooting percentage of the cuttings was increased. Similarly, GA improved both growth and rooting, and this effect was most distinct when the carbon dioxide concentration was 0.2 % (figure).

Discussion. Trials carried out in 1965 demonstrated that enrichment of the air in plastic houses with carbon dioxide stimulated the growth of grafts, seedlings and cuttings of forest tree plants, a result which confirmed those obtained in the previous year. The increase in length may be as much as 20—50 % greater than under normal conditions. The differences were most evident in healthy, vigorous pine grafts as well as seedlings and cuttings of pine and birch. The previously recommended CO_2 level of 0.2 % was found in these trials, as in numerous other experiments on horticultural crops, to be unnecessarily high, since 0.1 % had the same beneficial effect. Application of the gas can take place for a period of four hours in the morning.

The color of the light is known to be important from the standpoint of photosynthesis, since red light is most effective and blue light also is more beneficial than the other regions of the spectrum. In trials carried out at Viik it was observed that plants grew better when they were illuminated with red light for 15 hours daily than in white light for the same length of time. The best growth was achieved when, in addition to normal daylight, the plants were given supplementary red light at night, with Floralux lamps.



I II III IV

Birch cuttings, unsprayed (I), treated with gibberellic acid at 100 ppm (II), 200 ppm (III) and 300 ppm (IV) in plastic house with CO_2 0.2 %. Haapastensyrjä, Loppi, Sept. 2, 1965.

Experiments made with gibberellic acid as well as with mixtures of this chemical and NAA gave results which differed completely from those obtained by Japanese workers on coniferous plants. GA at rates of 100—200 ppm stimulated only those plants which were healthy and in a state of vigorous growth. This effect was most clear when the CO_2 concentration was higher than normal. In contrast, GA at higher rates as well as in mixtures with NAA caused injuries or death of pine and birch plants. In no cases did these substances cause flowering, as occurred in the Japanese studies. Treatment with urea, which promotes the growth of many horticultural crops, was of no benefit to pine grafts.

On the basis of the above-described results, the growth, quality and root system of young forest tree plants can be improved by raising the CO_2 concentration in plastic houses to 0.1 % from propane burners, by illuminating with red light either in addition to daylight or at night, and by treating vigorous plants 2—4 times with gibberellic acid at a rate of 100—200 ppm. The cost of such measures as well as the economic gains achieved by them still remain to be established.

Summary. The effect of CO_2 enrichment on forest tree plants in plastic houses was investigated in 1964 and 1965. The trials showed a marked influence of CO_2 in increasing the length and weight of the plants and in promoting their root development. The gas was applied from propane burners at levels of 0.1 and 0.2 %, either at the hours 8—10 and 14—16 or at 6—10 AM. The growth was equally vigorous at 0.1 % CO_2 as at the higher level. There was no difference between the single 4-hour morning application and the two 2-hour daily applications.

Treatment with 100—200 ppm gibberellic acid stimulated growth when the plants were healthy and vigorously growing. GA at higher concentrations or mixed with NAA was injurious, especially to weak plants. No flower initiation was observed in pine grafts treated with GA.

Red light during the night promoted the growth of spruce and birch cuttings.

SELOSTUS:

HIILIDIOKSIDI-, VALO- JA KASVUAINEKOKEITA METSÄPUUNTAIMILLA

Hiilidioksidilisäyksen vaikutusta metsäpuiden taimikasvatuksessa on vuosina 1964 ja 1965 tutkittu Metsänjalostussäätiön jalostusasemilla muovihuoneissa. Kumpanakin vuonna oli 0.2 %:n hiilidioksidipitoisuudessa kasvaneiden taimien pituuskasvu, paino ja juuriston kehitys parempaa kuin normaaliolosuhteissa (CO_2 0.03 %) kasvaneiden taimien. Hiilidioksidilisäys tapahtui propaania polttamalla, ja jälkimmäisenä vuonna tutkittiin taimien kasvua CO_2-pitoisuuden ollessa sekä 0.1 että 0.2 %. Kaasutusta suoritettiin neljä tuntia päivässä, joko klo 8—10 ja 14—16 tai 6—10. Kasvu oli yhtä nopeata 0.1 ja 0.2 %:n pitoisuuksissa ja riippumatta siitä tapahtuiko kaasutus aamupäivällä vai kahdesti päivässä.

Käsittely 100—200 ppm gibberelliinillä (GA) lisäsi pituuskasvua terveillä, hyvin juurtuneilla kasveilla. Väkevämmät GA-pitoisuudet samoinkuin tämän aineen ja 1-naftyylietikkahapon (NAA) seos vioitti pahoin männyn vartteita. Gibberelliinikäsittelyt eivät edistäneet männynvartteiden kukanmuodostusta (taul. 3—5).

Yön aikana annettu punainen valo näytti edistävän kuusen ja koivun pistokkaiden kasvua (taul. 2).

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