technical notes

CO₂ Enriched Air Increased Growth of Conifer Seedlings

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"In enclosed spaces such as a greenhouse, supplementary lighting and enrichment of the atmosphere with CO₂ can be used to advantage to increase the growth of conifer seedling stock."

Abstract

The dry weight of 3-week-old seedlings of white spruce, Norway spruce, jack pine and Scots pine was 30-80% greater than the control when grown in atmospheres enriched 3- to 5-fold with carbondioxide. Seedlings also responded positively to a difference in light intensity. CO₂ enriched atmospheres might profitably be used for the short term propagation of tree seedlings grown in greenhouses.

L'apport de bioxyde de carbone favorise la croissance des semis de conifères

Résumé

Le poids anhydre des semis de trois semaines de l'Epinette blanche (*Picea glauca*), l'Epinette de Norvège (*Picea abies*), du Pin gris (*Pinus Banksiana*) et du Pin sylvestre (*Pinus sylvestris*) s'est trouvé augmenté de 30 à 80 pour cent comparativement au matériel-témoin lorsque l'essai s'effectuait en un milieu 3 à 5 fois plus riche que la normale en bioxyde de carbone.

Les semis réagirent aussi positivement à des intensités lumineuses différentes.

L'utilisation du CO₂ pourrait être bénéfique à la production des semis lors d'essais à court terme effectués en serre.

Introduction

Rapid growth of conifer seedlings is of value for early comparative studies in genetics, for accelerating the development of crowns large enough to bear sufficient cones and seed for breeding, and in the production of special planting stock. Controlled environments are used to determine optimal levels, combinations and cycles of environmental variables affecting seedling development. This report concerns the effect of carbondioxide concentration and light intensity on the initial growth of seedlings of two spruce and two pine species.

Sustained carbondioxide enrichment of the air, "CO₂ fertilisation", for increasing plant growth has been known since the turn of the century (Carr, 1961). At low light intensities, increase in CO₂ concentration above that of normal atmosphere (300 p.p.m. or 0.03%) has little effect on rate of CO₂

assimilation. The maximum rate of photosynthesis (saturation) is reached at progressively higher levels of CO₂ concentration as light intensity increases (Canham, 1966), Ford and Thorne (1967) reported an increase of about 50 per cent in dry weight of sugar beet, barley and kale when grown in a controlled atmosphere of 1,000 p.p.m. CO₂. A further enrichment to 3,300 p.p.m. increased dry weight slightly more, and doubling the light intensity from 3.7 to 7.7 cal dm⁻²min⁻¹ was equivalent to a tenfold increase in CO₂ concentration. In the same treatments, maize was significantly taller in enriched atmospheres, but the 30 per cent increase in dry weight was not statistically significant. Many other horticultural species have been grown at elevated CO₂ levels in greenhouses with positive, though variable, results. The response of tree species to carbondioxide enrichment has received little attention.

Materials and Methods

Seed of white spruce (*Picea glauca*), Norway spruce (*Picea abies*), jack pine (*Pinus banksiana*) and Scots pine (*Pinus sylvestris*) was grown in growth cabinets at three levels of CO₂ concentration, 300-400 p.p.m., ambient, 900 p.p.m., and 1,500 p.p.m., and at two light intensities. The light source was a mixture of cool-white fluorescent and tungsten filament lamps and shade was provided by a double layer of fiberglass screen. All lamps were on for 11 hours in the middle of a 15 hour photoperiod, providing 1,100 ft. c. in the shade and 2,800 ft. c. in the open. Illumination during the first and last hour was provided by the incandescent lamps only, with one intermediate step (2/3 fluorescent lamps) to maximum illumination. Carbondioxide levels were recorded and controlled through a system incorporating an infra-red gas analyser (M.S.A. Lira, Model 200) that admitted pure CO₂ gas to the cabinets as required. Light intensities were measured with a Weston Illumination Meter. Common conditions were maintained in each of three growth cabinets, including 25°C day temperature, 15°C night temperature, 60-80% relative humidity. Two tests (replications) were made of the same species × treatment combinations.

Seed of the four species was sown in 16 oz. plastic pots which were evenly distributed among the treatments. Nutrient solution (Ingestad, 1967) was applied as required to maintain adequate moisture and nutrients in the rooting medium of mixed sand and peatmoss. The results are based on mean dry-weight of seedlings (cotyledons + primary needles) thinned from the pots 21 days following germination.

Results

Seedling response to CO₂ concentration and light intensity is illustrated in Figs. 1a-d. Both enriched CO₂ atmospheres and full light intensity significantly increased dry-weight of all species and the effects of the two factors were independent within the limits of experimental error (Table I). The low values of the variance ratios listed in Table 1 for Norway spruce are the result of uneven germina-

tion among pots that led to a relatively large error variance at this early stage of the test. For each species, the effect of the highest level of CO₂ (1,500 p.p.m.) was not significantly better or worse than that of the three-fold increase (900 p.p.m.) over the normal ambient level. The proportional increases in dry-weight resulting from 900 p.p.m. CO₂ over both light intensities and due to full light exposure over all CO₂ levels are listed in Table 2. The spruces reacted more to CO₂ enrichment than did the pines, but the pines responded more to the variation in light intensity.

Discussion

The optimal light intensity at the temperature and photoperiod employed cannot be specified from this exploratory test. The differential response to light intensity of spruce and pine appears to be related to differences in the scale of shade tolerance. Baker (1950) rated white spruce as tolerant, jack pine as very intolerant. A three-fold increase to 900 p.p.m. in the concentration of CO₂ in the atmosphere markedly increased its assimilation by young seedlings of the four species grown. No benefit was apparent from a further two-fold increase in CO₂ concentration. Further tests in controlled environments will be made to find optimal combinations of temperature, light and CO₂ to accelerate the growth of pine and spruce species of major economic interest.

In enclosed spaces such as a greenhouse, supplementary lighting and enrichment of the atmosphere with CO₂ can be used to advantage to increase the growth of conifer seedling stock. Such methods for growth stimulation are commonly used in horticultural practice and may find particular application in forestry for the production of container grown seedlings and special purpose stock required in research.

Table 1. Analyses of variance: F ratios for treatments by species

Treatments	d.f.	White spruce	Norway spruce	Jack pine	Scots pine
		F	F	F	F
CO ₂	2	32.7**	6.1*	21.6**	9.1*
Light	1	87.3**	5.9*	148.9**	83.8**
CO ₂ x Light	2	2.8 ^{ns}	0.3 ^{ns}	2.0 ^{ns}	1.5 ^{ns}

Significance levels: **, .01; *, .05; ns, not sig.

Table 2. Effects of CO₂ alone and light alone on mean epicotyl dry-weight

	Proportional increase due to CO ₂		Proportional increase due to Light	
	900/300-400 ppm per cent		2,800/1,100 ft.c per cent	
White spruce.....	61		58	
Norway spruce.....	78		45	
Jack pine.....	40		69	
Scots pine.....	32		69	

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Fig. 1. Response diagrams of four species: dry-weight of mean seedling top in relation to carbondioxide concentration in air and to light intensity.