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FUELS FROM WOODY BIOMASS PROGRESS REPORT

FOR PERIOD: JANUARY 1980 TO MAY 1980

ON

ENERGY BIOMASS TREE SEEDLING PRODUCTION STUDY

CONTRACT NUMBER ET-78-C-02-4909

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PREPARED BY:

THE GENERAL ELECTRIC COMPANY

CONTROLLED ENVIRONMENT AGRICULTURE OPERATION

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DISCLAIMER

INTRODUCTION

General Electric Controlled Environment Agriculture Operation has utilized for this research program a system known as GENIPONICS^{TM}, which was developed by General Electric's Controlled Environment Agriculture Operation (CEAO) in Syracuse, New York. A complete description of this totally controlled plant growing system is available in the "Fuels from Woody Biomass Progress Report" prepared by CEAO and submitted in March 1980.

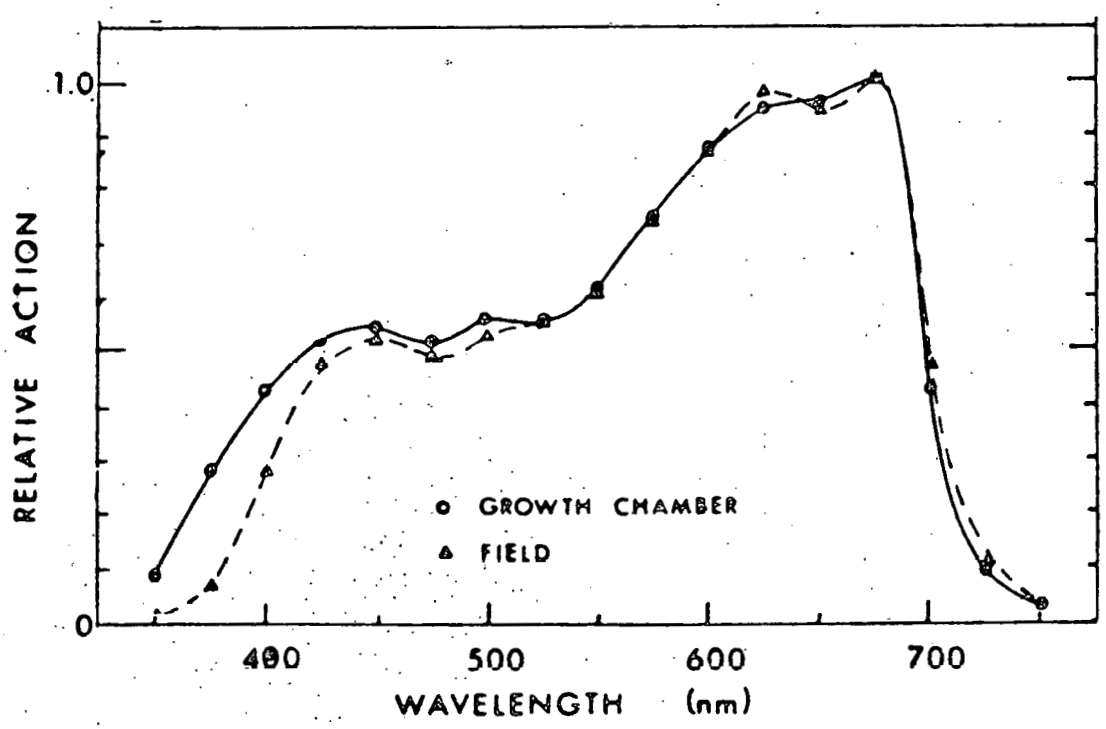
The Geniponics system employs two types of high intensity discharge lamps as its source of illumination for plant growth. The effectiveness of lamps for plant growth is determined by two factors. First, the proportion of electrical energy which is converted to radiant energy in the visible portion of the spectrum (400-700 nm). Second, by the spectral energy distribution (SED) curve of the lamp across the range of photosynthetically active radiation (PAR) (380 nm to 750 nm).

The lamps efficiency and lumen output maintenance are important economic criteria in the operation of a large-scale commercial growth chamber. The 1000 watt high pressure sodium lamp (Lucalox^{R}) is one of the most efficient lamps available, yielding 120-140 lumens per watt and an average life expectancy exceeding 20,000 hours. The high pressure metal halide lamp (Multi-Vapor^{R}) is somewhat less efficient than the high pressure sodium lamp yielding 80-100 lumens per watt.

The lamps SED curve is important in controlling plant growth. In terms of photosynthetic energy utilization, red radiation is most efficient. A blue light quantum contains a higher energy (2.8 EV @ 450 nm) than a red quantum (1.9 EV @ 6.80 nm).

When a blue quantum is absorbed by the chlorophyll molecules, a portion of its energy is immediately dissipated as heat resulting in the same energy as that resulting from the absorption of a red quantum. Also pigments absorbing in the blue region do not fully transfer the energy absorbed. This accounts for the 2:1 ratio of plant sensitivity at 680 nm and 450 nm as described by McCrees relative action curve (below). The other light activated plant process mechanisms (photomorphogenesis, photoperiodism and phototropism) require much lower threshold intensities of absorbed quanta. A lamp having the majority of its energy concentrated in the longer wavelengths in the upper portion of the relative action curve may be a more effective lamp than one with a SED curve more closely matching the relative action curve, particularly when overall lamp efficiency and costs are considered.

The experiments discussed in this report were designed to evaluate the seedling growth response of several candidate species to the two types of high intensity discharge lamps and a combination of these two lamps used in the Geniponics system of controlled environment agriculture.



METHODS AND MATERIALS

Two lamp evaluation studies were conducted in the Geniponics system to determine the effect, if any, of various light treatments on tree seedling growth. A sixteen (16) hour photoperiod followed by an uninterrupted eight (8) hour dark period was utilized for this test series. Temperatures during the light period were held at 27°C $\pm$ 1°C. Carbon dioxide levels were maintained at 1500 parts per million during the light period. The tree seedlings were sub-irrigated with a high phosphate nutrient solution previously described in the progress report.

Data was collected from twenty-five (25) randomly selected seedlings from each of the replicated containers from each treatment. Heights were recorded to the nearest tenth of a centimeter. Root collar diameters, taken at media-atmosphere interface, were recorded to the nearest one-hundredth of a millimeter as measured with a Helios metric vernier caliper. Dry weights were recorded to the nearest ten-thousandth of a gram on a Sartorius 2003 MPI analytical recording balance. Light measurements were made with a Lambda Instruments LI-170 meter with quantum sensor.

Preliminary Lamp Evaluation Experiment

Three equalized evaluation areas were partioned with an aluminized reflective material in order to eliminate radiation overlap. The lamp treatment areas were large enough not to impede air movement, thereby maintaining consistent ambient conditions between treatment areas.

The lamp evaluation areas contained GE high intensity discharge lamps: one with Lucalox^{R} - a high pressure sodium; one with Multi-Vapor^{R} - a metal halide type and another with a 2:1 combination of sodium to metal halide lamps. Lamps were arranged to provide an equal quantum flux of photosynthetically active radiation (400-700 nm) at a level 30 centimeters above the growbed. Two intensities were provided within each lamp treatment - 500 $\mu\varepsilon\ m^{-2}\ sec^{-1}$ and 250 $\mu\varepsilon\ m^{-2}\ sec^{-1}$.

Each specie was replicated twice within each treatment. Platanus occidentalis, American sycamore, was grown in the Spencer-Lamaire "5" container at a density of 81 seedlings per square foot and media volume of 3.5 cubic inches. Robinia pseudoacacia, black locust, was grown in the Styroblock 4A container providing a density of 87 seedlings per square foot and a media volume of 3.8 cubic inches. Data from the Robinia was collected 35 days from seeding and at 56 days from seeding for the Platanus.

Lamp Evaluation Experiment

The two treatment areas were partitioned as previously described. Lucalox^{R}, high pressure sodium lamps, provided 500 $\mu\varepsilon\ m^{-2}\ sec^{-1}$ in one treatment as did the Lucalox^{R} and Multi-Vapor^{R} combination in the other area. Lamps were spacially arranged as to provide uniform radiation by lamp type throughout the test area. The metal halide lamps contributed 175 $\mu\varepsilon\ m^{-2}\ sec^{-1}$ (approximately 35%) to the 500 $\mu\varepsilon\ m^{-2}\ sec^{-1}$ lamp combination treatment area.

The growth response of four candidate species was evaluated. Robinia pseudoacacia, black locust, and Alnus glutinosa, European black alder, were grown in the Spencer-Lamaire "5" container at a density of 81 seedlings per square foot with a media volume of 3.5 cubic inches. Platanus occidentalis, American sycamore, and Liquidambar styraciflua, sweetgum, were grown in the Spencer-Lamaire "Hillson" container at 37 seedlings per square foot with 10 cubic inch volume. Liquidambar and Alnus were also grown in the Styroblock 4 container at 75 seedlings per square foot and 4.0 cubic inches media volume.

The Robinia and Platanus seedlings were harvested at 35 and 56 days respectively. The Alnus seedlings were harvested at 60 days, and the Liquidambar at 70 days from seeding.

RESULTS

PRELIMINARY LAMP EVALUATION TEST

Robinia pseudoacacia, black locust seedlings were grown for 35 days in Spencer-Lamaire "5" containers. Under the high light intensity treatment of 500 $\mu\varepsilon$ m^{-2} sec^{-1}, no differences were found in height or root collar diameter between the three lamp treatments. In dry matter production plants from both the sodium and the metal halide treatments showed superior dry weights as compared to those plants from the combination lamp treatment. There was no statistical difference in dry matter production between the sodium and the metal halide lamp treatments. An index to plant sturdiness (S.I.) commonly used is ug shoot dry weight per centimeter height; this followed the pattern of the dry weights.

500 $\mu\varepsilon$ m^{-2} sec^{-1}

	$\bar{x}$ ht. (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	S.I. mg/cm
High Pressure Sodium	46.48 ± 7.17	2.89 ± 0.36	1.6759 ± 0.536	0.2136 ± 0.07	0.128	35.7
Sodium and Metal Halide	43.77 ± 8.22	2.75 ± 0.46	1.2518 ± 0.567	0.1639 ± 0.072	0.131	27.8
Metal Halide (Multi-Vapor)	44.07 ± 8.04	2.84 ± 0.46	1.6270 ± 0.793	0.2284 ± 0.103	0.140	36.4

The analysis of the data comparing the three lamp treatments from the low light treatment of 250 $\mu\varepsilon$ m^{-2} sec^{-1}, indicates differences in mean heights. The high pressure sodium treatment resulted in plants with the greatest height followed by the metal halide and then the mixture of both lamps. The root dry weights were significantly greater in the sodium treatment when compared to the other two. The lamp mixture did not improve these weights over the metal halide treatment. The metal halide lamps gave the sturdiest plants but with the lowest root to shoot ratio. It is of interest that the metal halide lamps produced a shorter plant but with the same shoot dry weight and therefore the highest S.I.

250 με m^{-2} sec^{-1}

	$\bar{x}$ ht. (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt (gm)	R/S	S.I. mg/cm
High Pressure Sodium	45.87 ± 6.02	2.69 ± 0.40	1.2665 ± 0.483	0.1829 ± 0.066	0.144	27.6
Sodium and Metal Halide	42.13 ± 7.25	2.74 ± 0.42	1.2577 ± 0.601	0.1512 ± 0.72	0.120	29.8
Metal Halide	36.96 ± 5.66	2.61 ± 0.37	1.2590 ± 0.470	0.1410 ± 0.054	0.112	34.1

The intra-lamp treatment intensity evaluation produced the following results:

High Pressure Sodium

	$\bar{x}$ ht. (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	S.I. mg/cm
500 με	46.48 ± 7.17	2.89 ± 0.36	1.6759 ± 0.536	0.2136 ± 0.070	0.128	35.7
250 με	45.87 ± 6.02	2.69 ± 0.40	1.2665 ± 0.483	0.1829 ± 0.066	0.144	27.6

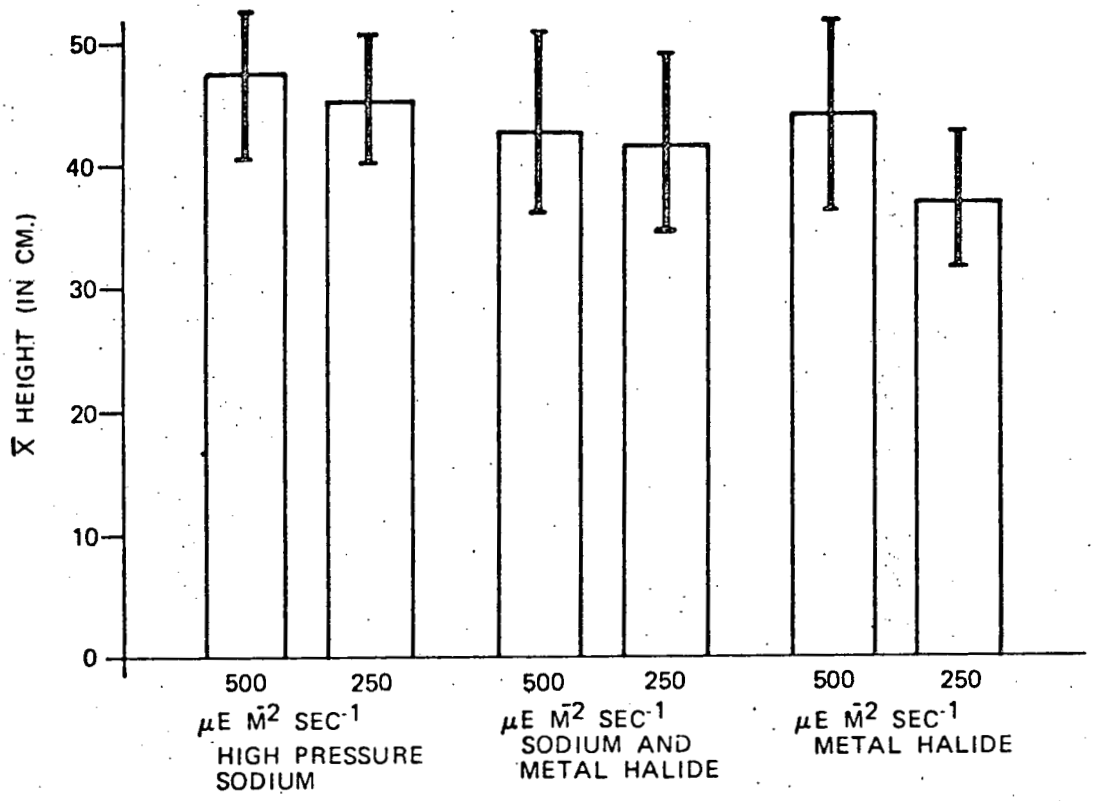
Under the sodium light the Robinia seedlings responded more productively to the 500 με m^{-2} sec^{-1} intensity. Mean height growth was not shown to be significantly greater.

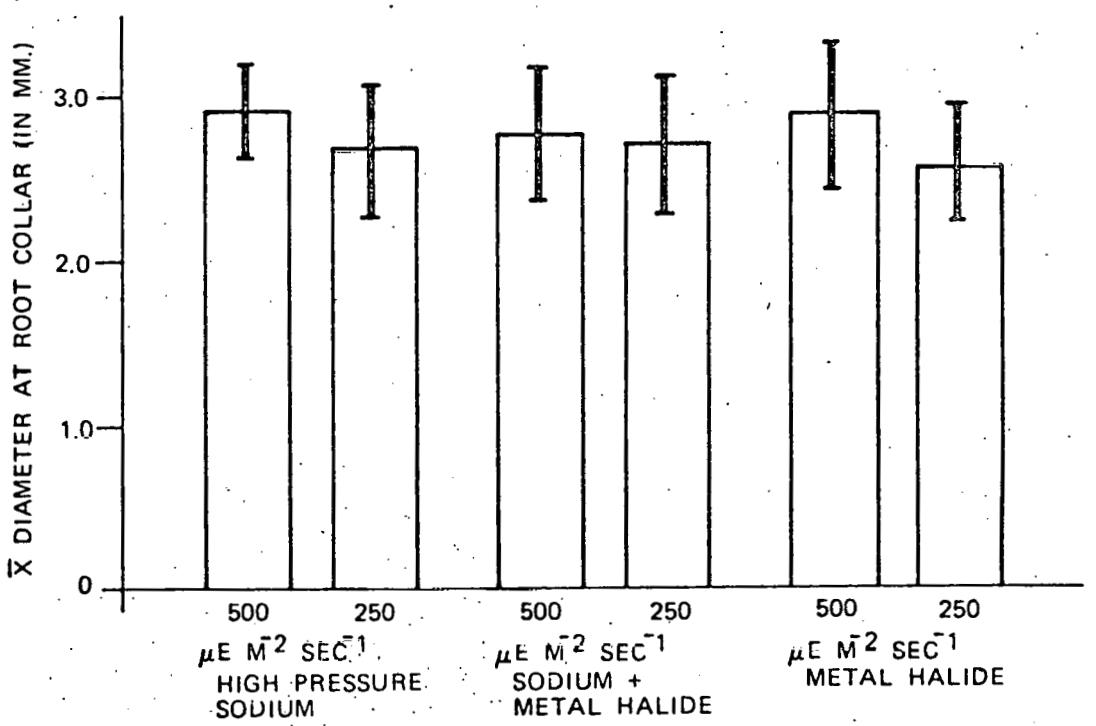
2:1 Sodium to Metal Halide

	$\bar{x}$ ht. (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	S.I. mg/cm
500 με	43.77 ± 8.22	2.75 ± 0.46	1.2518 ± 0.567	0.1639 ± 0.072	0.131	27.8
250 με	42.13 ± 7.25	2.74 ± 0.42	1.2577 ± 0.601	0.1512 ± 0.072	0.120	29.8

Statistically, there were no differences in this treatment for Robinia grown at this density. This has some interesting implications to be discussed later.

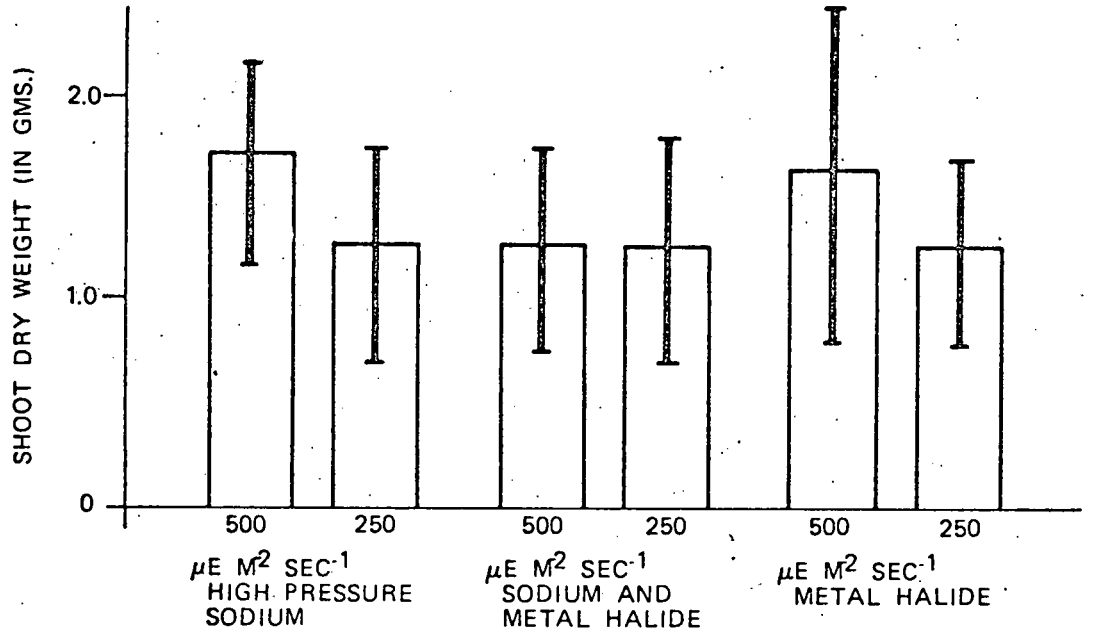
Robinia pseudoacacia
35 days from seeding

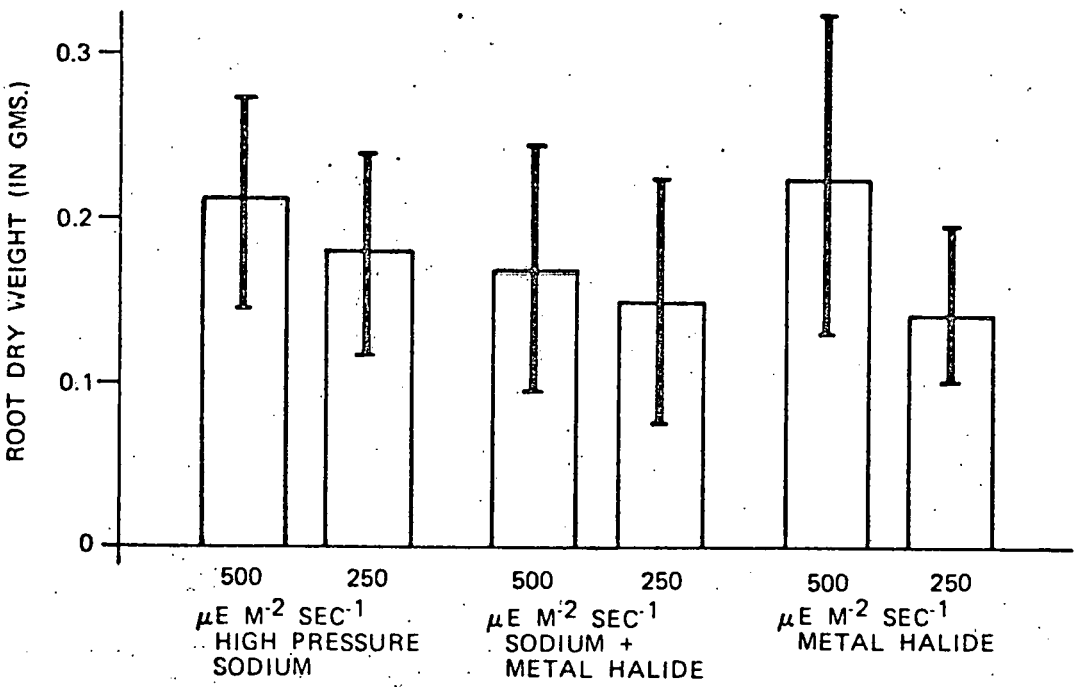




$\bar{X}$ OF 2 REPLICATES OF 25 SEEDLINGS EACH $\bar{X} \pm$ S.D.

Robinia pseudoacacia
35 days from seeding





$\bar{X}$ OF 2 REPLICATES OF 25 SEEDLINGS EACH

Metal Halide

	$\bar{x}$ ht. (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	S.I. mg/cm
500 με	44.07 ± 8.04	2.84 ± 0.46	1.6270 ± 0.793	0.2284 ± 0.103	0.140	36.4
250 με	36.97 ± 5.66	2.61 ± 0.37	1.2590 ± 0.470	0.1410 ± 0.054	0.112	34.1

As is the case in the sodium comparison, the Robinia seedlings responded much more favorably to the 500 $\mu\varepsilon\ m^{-2}\ sec^{-1}$ radiation level. Each parameter measured was significantly increased by the higher intensity. The plants responded similarly to the two intensities in terms of root to shoot ratio and in sturdiness index.

Platanus occidentalis, American sycamore, was grown in the Spencer-Lamaire "5" for 56 days from seeding. Under the 500 $\mu\varepsilon\ m^{-2}\ sec^{-1}$ intensity treatment no statistical differences were found between the sodium and the combination lamp systems. However, significant differences were demonstrated with both the sodium and the combination systems when compared to the metal halide lighting system except in recovered root dry weights. It is of particular interest to note that the index of plant sturdiness was 60 mg/cm.

500 $\mu\varepsilon\ m^{-2}\ sec^{-1}$

	$\bar{x}$ ht. (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	mg shoot per cm ht
High Pressure Sodium	29.85 ± 7.98	3.70 ± 1.09	1.7897 ± 1.413	0.2395 ± 0.186	0.134	59.9
Sodium and Metal Halide	32.85 ± 7.14	3.31 ± 1.01	1.4345 ± 1.031	0.1871 ± 0.132	0.130	43.7
Metal Halide	20.99 ± 3.55	2.71 ± 0.67	0.9248 ± 0.739	0.2038 ± 0.140	0.220	44.1

The analysis of the sodium and the combination treatments when compared to the metal halide provided only one difference at the 250 με level of illumination. The mean height of the seedlings under the mixture was found to be greater than that of the metal halide. The combination lighting also showed significantly higher dry weights than the sodium treatment. Under this lower illumination level, the seedlings in the sodium lamp treatment provided the lowest value of plant sturdiness and shoot dry weight. It should be noted that the standard deviations of the dry weights were nearly as great or greater than their means.

250 με m^{-2} sec^{-1}

	$\bar{x}$ ht (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	mg shoot per cm ht
High Pressure Sodium	24.51 ± 5.82	2.59 ± 0.67	0.7632 ± 0.683	0.1045 ± 0.080	0.137	31.1
Sodium and Metal Halide	27.22 ± 5.85	3.01 ± 0.94	1.1666 ± 1.182	0.1652 ± 0.190	0.142	42.9
Metal Halide	20.73 ± 5.35	2.42 ± 0.86	0.8208 ± 0.735	0.1197 ± 0.107	0.145	39.6

In the intra-lamp treatment intensity analysis, the following data were collected for the high pressure sodium system:

	$\bar{x}$ ht (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	mg shoot per cm ht
500 με	29.85 ± 7.98	3.70 ± 1.09	1.7897 ± 0.763	0.2395 ± 0.105	0.134	60.0
250 με	24.51 ± 5.82	2.59 ± 0.67	1.4127 ± 0.683	0.1863 ± 0.080	0.137	31.1

The high level sodium lamp radiation showed the greatest differences of the treatments examined. Each parameter showed a high level of significant difference. The plant sturdiness index was nearly doubled by a doubling in quantum flux.

2:1 Sodium to Metal Halide

	$\bar{x}$ ht (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	mg shoot per cm ht
500 με	32.85 ± 7.14	3.31 ± 1.01	1.4345 ± 1.031	0.1871 ± 0.132	0.130	43.7
250 με	27.22 ± 5.85	3.01 ± 0.94	1.1666 ± 1.182	0.1652 ± 0.190	0.142	42.9

Only the height was shown to be affected by the intensity differences in the combination lamp treatment. As would be expected, the shoot dry matter production is closely correlated with height growth as indicated by the sturdiness index values.

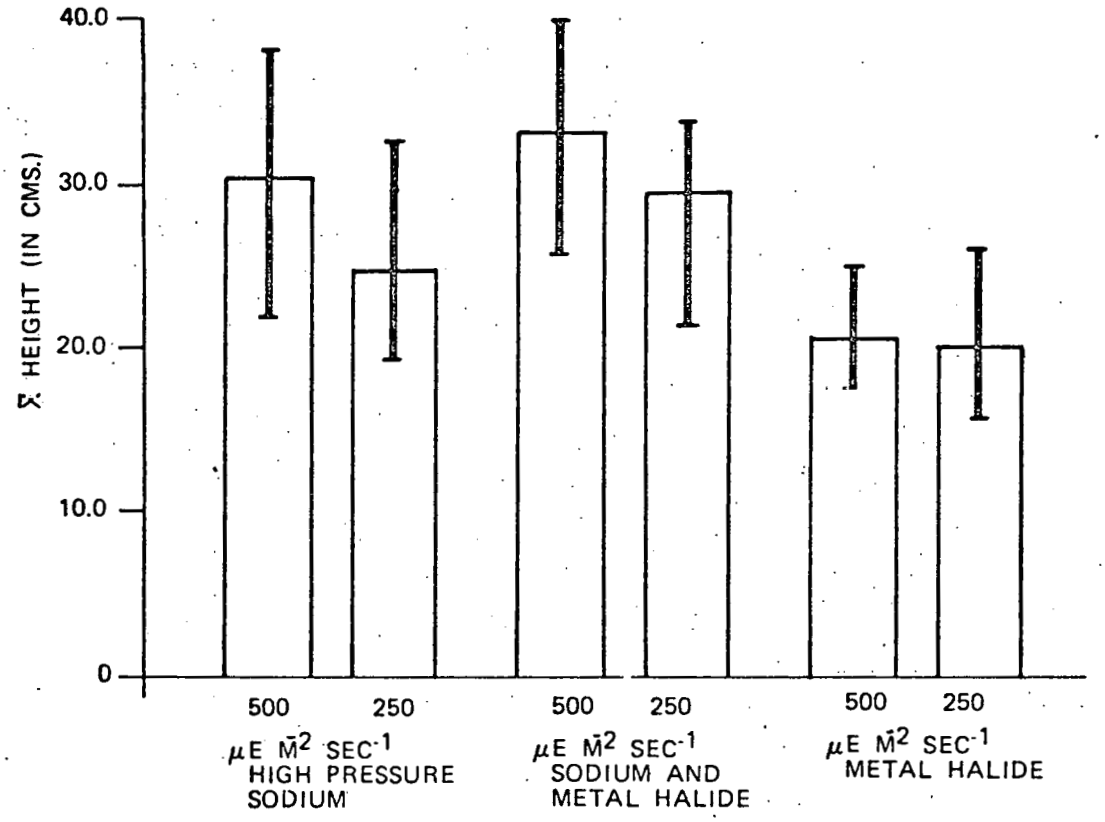
Metal Halide

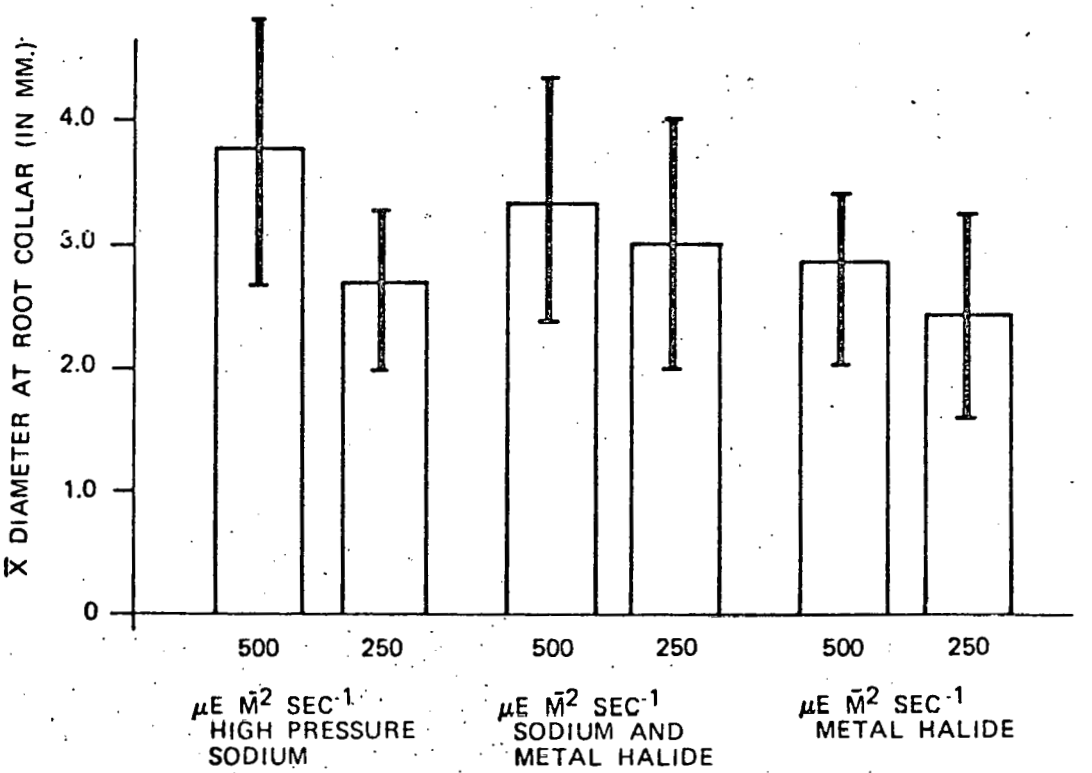
	$\bar{x}$ ht (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	mg shoot per cm ht
500 με	20.99 ± 3.55	2.71 ± 0.67	0.9248 ± 0.821	0.2083 ± 0.140	0.220	44.1
250 με	20.73 ± 5.35	2.42 ± 0.86	0.7394 ± 0.735	0.1197 ± 0.107	0.145	39.6

Root dry weight is considered to be of importance as an indicator of seedling establishment survival and subsequent growth potential after outplanting. This comparison yielded a 74% increase in dry weight of the recovered roots under the 500 με m^{-2} sec^{-1} level of irradiation.

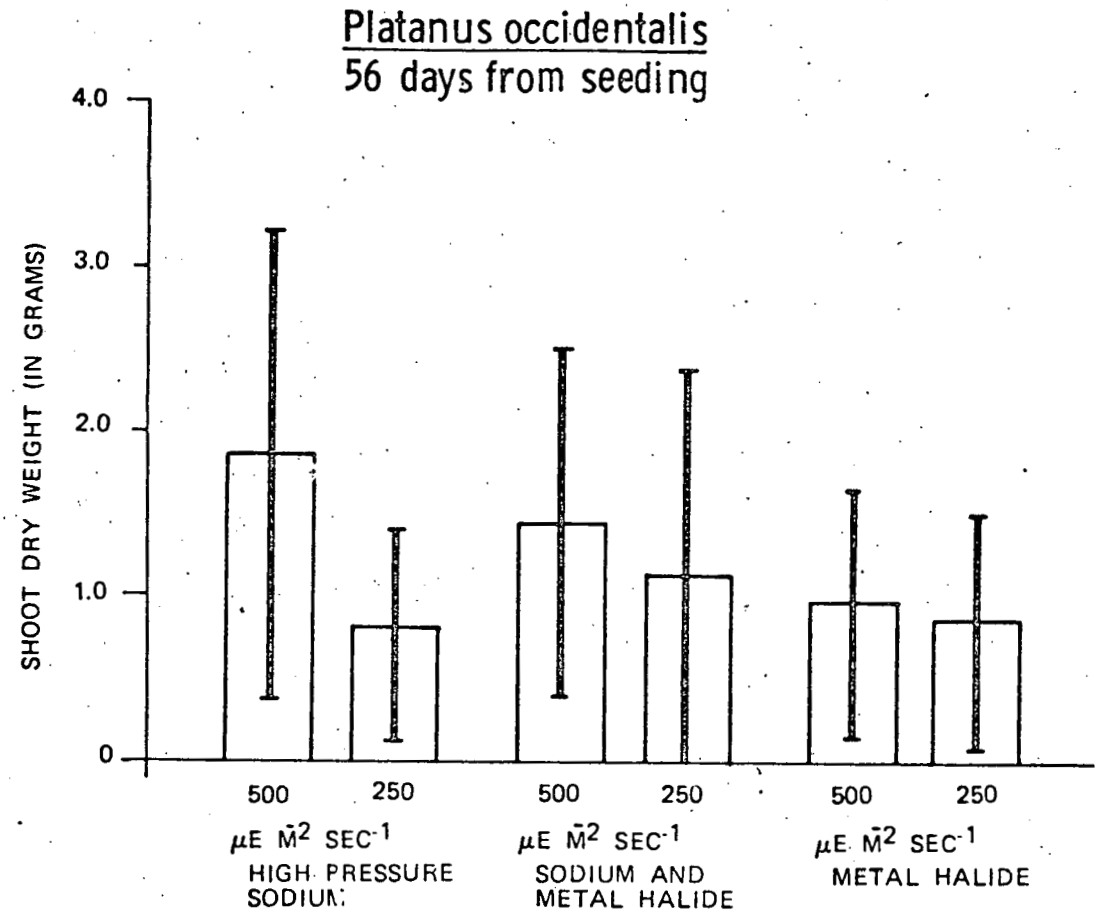
The Platanus seedlings grown in the Spencer-Lamaire "Hillson" container failed to show a significantly different response to the lighting treatments in any parameter measured. The Hillson container did produce the largest and most uniform crop of Platanus seedlings grown todate in the standard 56 day production period.

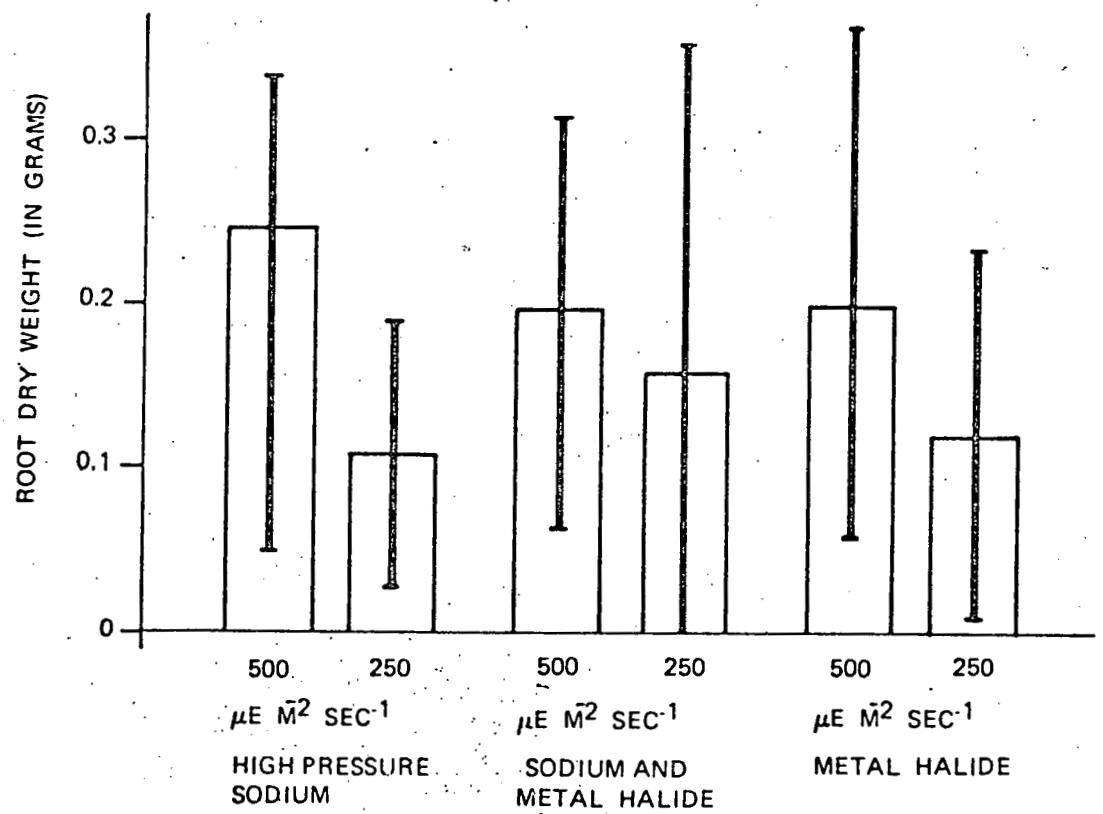
Platanus occidentalis
56 days from seeding





$\bar{X}$ OF 2 REPLICATES OF 25 SEEDLINGS EACH


Platanus occidentalis
56 days from seeding
SHOOT DRY WEIGHT (IN GRAMS)
4.0
3.0
2.0
1.0
0
500
250
500
250
500
250
μE M² SEC⁻¹
HIGH PRESSURE SODIUM
μE M² SEC⁻¹
SODIUM AND METAL HALIDE
μE M² SEC⁻¹
METAL HALIDE


ROOT DRY WEIGHT (IN GRAMS)
0.3
0.2
0.1
0
500
250
500
250
500
250
μE M² SEC⁻¹
HIGH PRESSURE SODIUM
μE M² SEC⁻¹
SODIUM AND METAL HALIDE
μE M² SEC⁻¹
METAL HALIDE

Platanus occidentalis

Spencer-Lamaire "Hillson"

	$\bar{x}$ ht (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	S.I. mg/cm
High Pressure Sodium	48.66 ± 4.10	4.19 ± 0.69	2.5800 ± 1.10	0.3595 ± 0.173	0.140	53.0
Sodium and Metal Halide	50.02 ± 3.75	4.12 ± 0.58	2.6910 ± 1.0	0.3353 ± 0.132	0.127	53.8

It is of interest to point out that in the previous experiment when the Platanus seedlings were grown in the Spencer-Lamaire "5" containers at about twice the density (81 vs 37 seedlings per square foot) the S.I. value for the sodium treatments at 500 $\mu\varepsilon\ m^{-2}\ sec^{-1}$ was 59.9 mg/cm and the sodium and metal halide was 43.7 mg/cm.

Robinia pseudoacacia was grown in the Spencer-Lamaire "5" container through its normal 35 day production period. The Robinia seedlings responded dramatically to the sodium lighting, showing a very significant increase in each parameter.

	High Pressure Sodium	Sodium and Metal Halide
$\bar{x}$ height (cm)	48.03 ± 6.36	45.16 ± 3.63
$\bar{x}$ diameter at root collar (mm)	3.03 ± 0.33	2.42 ± 0.30
$\bar{x}$ shoot dry weight (gm)	1.80 ± 0.44	1.34 ± 0.34
$\bar{x}$ root dry weight (gm)	0.16 ± 0.05	0.11 ± 0.03
root:shoot	0.089	0.082
S.I. mg/cm	37.5	29.7

Although the recovered root dry weights were slightly lower in this run, the data tends to recapitulate the previous experiment.

Liquidambar styraciflua seedlings were evaluated in two very different containers. The seedlings were grown for 70 days in the Spencer-Lamaire Hillson (37 seedlings per square foot with a ten cubic inch volume) and the Styroblock 4 (75 seedlings per square foot with 4.0 cubic inch volume). The seedlings grown in the Hillson, like the Platanus, failed to respond significantly different to the light treatments in any parameter measured.

Liquidambar styraciflua - 70 Days From Seed

	Spencer-Lamaire Hillson		Styroblock 4	
	High Pressure Sodium	Sodium & Metal Halide	High Pressure Sodium	Sodium & Metal Halide
$\bar{x}$ height (cm)	42.29 ± 3.42	43.14 ± 3.65	42.29 ± 3.30	38.35 ± 2.39
$\bar{x}$ diameter at root collar (mm)	3.86 ± 0.55	4.09 ± 0.69	3.41 ± 0.40	3.28 ± 0.46
$\bar{x}$ dry weight of leaves (gm)	1.847 ± 0.594	1.995 ± 0.58	1.352 ± 0.303	1.341 ± 0.404
$\bar{x}$ stem dry weight (gm)	0.786 ± 0.240	0.784 ± 0.24	0.598 ± 0.143	0.530 ± 0.133
$\bar{x}$ root dry weight (gm)	0.389 ± 0.134	0.415 ± 0.15	0.278 ± 0.687	0.26 ± 0.078
root:shoot	0.148	0.149	0.143	0.143
S.I. (mg/cm)	62.3	64.4	46.1	48.8

The Liquidambar seedlings grown in the Styroblock "4" responded favorably to the sodium lamp treatment in dry matter production. No statistical difference was measured in other parameters.

Comparison of containers indicates very significant increases in all measured parameters for those seedlings grown in the Spencer-Lamaire Hillson container except the root to shoot ratio and the $\bar{x}$ height under the high pressure sodium treatment.

Alnus glutinosa seedlings when grown in the Spencer-Lamaire 5 were the only species which produced a superior seedling under the high pressure sodium lamp and metal halide lamp mix. This illumination system produced a 19% increase in recovered root dry weights and a 10% increase in shoot dry weights with a corresponding increase in plant sturdiness.

Spencer-Lamaire "5" Container

	$\bar{x}$ ht (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ shoot dry wt(gm)	$\bar{x}$ root dry wt(gm)	R/S	S.I. mg/cm
High Pressure Sodium	47.75 ± 4.56	3.78 ± 0.61	1.622 ± 0.50	0.245 ± 0.13	0.151	34.0
Sodium and Metal Halide	48.80 ± 4.91	3.78 ± 0.58	1.778 ± 0.29	0.292 ± 0.14	0.164	36.4

Alnus seedlings grown in the Styroblock 4 container followed the previous trends with respect to growth responses achieved under 100% high pressure sodium lighting. The root collar diameter was increased by 16%, while the other measured parameters were not significantly different.

Styroblock "4" Container

	$\bar{x}$ ht (cm)	$\bar{x}$ diam. (mm)	$\bar{x}$ leaves dry wt(gm)	$\bar{x}$ stem dry wt(gm)	$\bar{x}$ dry wt root (gm)	R/S	S.I. mg/cm
High Pressure Sodium	47.36 ± 4.13	3.86 ± 0.56	1.006 ± 0.301	0.539 ± 0.142	0.290 ± 0.122	0.188	32.6
Sodium and Metal Halide	48.16 ± 3.37	3.34 ± 0.51	0.925 ± 0.272	0.537 ± 0.167	0.280 ± 0.127	0.192	30.3

DISCUSSION

The initial lamp evaluation was designed to make a preliminary investigation into the growth response of two candidate species and the effects of two light intensities and three lamp treatments. Under this set of growth conditions, both the Robinia and the Platanus seedlings proved to be most productive under the 500 $\mu\varepsilon$ m^{-2} sec^{-1} level of irradiation from high pressure sodium lamps. Statistically, the Robinia seedlings performed equally well under the metal halide lamps. The Platanus seedlings responded equally well to the sodium/metal halide combination treatment.

In the 250 $\mu\varepsilon$ m^{-2} sec^{-1} treatments, the Robinia seedlings under each of the lamp treatments proved to be equally productive in shoot dry matter. The highest root dry weights were recorded under the sodium treatment and for this reason the Robinia appear to respond slightly better to the sodium lamps at this lower radiation level. When compared to the sodium light treatment the Platanus seedlings showed a significant increase in dry matter production under the sodium/metal halide combination.

Neither specie showed a significantly different response to the two light intensities under the combination lamp system. In both of the other lamp treatments, the seedlings showed significant increases in dry matter production under the higher light intensities.

The second phase of the lamp evaluation was designed to examine the seedlings productivity at a 500 $\mu\varepsilon$ m^{-2} sec^{-1} intensity for a 16-hour photoperiod under the high pressure sodium and under a 2:1 combination sodium to metal halide. In this experiment four candidate species were grown in a much larger production run. Liquidambar and Platanus seedlings were grown in Spencer-Lamaire "Hillson" containers at approximately half the densities previously used (37 seedlings per square foot versus 75-87 seedlings per square foot). In this container, at a much reduced density, no significant differences were observed between lamp treatments.

The Platanus responded more to the increased available growing space than did the Liquidambar seedlings, although there were dramatic increases in dry matter production with the Liquidambar seedlings grown at 37 seedlings per square foot compared to 75 seedlings per square foot.

At the higher densities both the Liquidambar and the Robinia seedlings responded much more favorably to high pressure sodium lighting. The Alnus seedlings were grown at high densities, 81 and 75 seedlings per square foot in the Spencer-Lamaire "5" container and in the styroblock 4 respectively. The seedlings grown in the Spencer-Lamaire container were the only seedlings which increased productivity under the combination lamp system. The seedlings grown in the styroblock 4 followed the trend of the other species evaluated at the higher densities.

An evaluation of the data derived from this study appears to indicate the superior productivity and uniformity of these seedlings grown under the higher irradiation level from the high pressure sodium lamps and appears to be independent of density. Of particular interest is the evidence presented here that neither the Robinia or the Platanus seedlings showed a significantly different response in dry matter production, to the two intensities investigated under the sodium-metal halide combination lamp treatment. This indicates the need to consider a longer photoperiod of lower intensities. Continuous illumination would be a preferred method, since lamp life can be extended by up to 50% for the high pressure sodium lamp, and up to 100% for the metal halide lamp when burned continuously as opposed to cyclic operation. This procedure should improve the production economics since fewer lamps would be required and overall electrical usage would be reduced.

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