of many pathogens which a weaker plant might not be able to withstand.

PETER VERMEULEN: Is it essential to use a synthetic mix?

DON KRIZEK: No it is not. We started out by using regular composted soil but the quality varied so much from one batch to another that we went to a synthetic mix to have more uniformity. We have obtained excellent results with this peat-lite mix.

RALPH SHUGERT: In your opinion, would the check plants catch up with the *Betula* which were grown under optimum conditions and were considerably larger than those of the check, if both were planted out into a transplant bed?

DON KRIZEK: We are in the process of running such studies now but based upon what we have done thus far with herbaceous plants, there is no reason not to expect that woody plants started under controlled-environment conditions would not also maintain their lead in growth over check plants provided that nutrition or some other factor did not become limiting.

KNOX HENRY: You reported working with 2000 ppm CO_2 but, in some work we have been doing, 1200 ppm seems to be about the maximum that is necessary. I wonder if you would comment on this.

DON KRIZEK: The optimum CO_2 would depend to a large degree on the light, temperature, and other factors which you may be using. At lower temperatures, particularly, you may well be saturating your system at 1200 ppm of CO_2.

PAUL READ: Have you looked at growth regulator effects and interactions with your other factors?

DON KRIZEK: Not as yet. There are many environmental interactions that we need to examine before we begin studies on growth regulator effects and chemical and environmental interactions, although these certainly need to be done.

MODERATOR FORSTER: In continuing our interest in controlling the plants environment, I'd like to introduce to you now a fellow Canadian, Mr. Joe Molnar who is interested in plant propagation and CO_2 work.

CARBONIZED MIST IN PLANT PROPAGATION

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Introduction:

The propagation of horticultural plants is an important aspect of the nursery and bedding plant industry. Many species and cultivars are difficult or impossible to propagate from

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cuttings. Any technique that will increase the number of species which may be propagated, or reduce the time and space used for propagation will assist the industry.

The use of CO_2 may be helpful in propagation. Wittwer (5) and Voipio (4) reported strong root development of plants grown in an atmosphere enriched with CO_2. Carpenter (1) found that lettuce and chrysanthemum grown in a mist of carbonated water weighed three times more than plants from the check. At Morden, we found that when young vegetables and ornamental plants were grown in CO_2 enriched atmospheres a superior root system was developed. These observations led us to our propagation experiments.

METHODS:

The first experiments were conducted in controlled environment with a CO_2 enriched atmosphere; the second in the greenhouse where the plants were kept moist with carbonated mist and similar experiments were conducted outdoors (2).

Controlled Environment:

The rooting of Chrysanthemum '6408' *Weigela* 'Centennial' and *Potentilla fruticosa* 'Coronation Triumph' was studied in an atmosphere enriched with CO_2 in growth rooms. Two rooms were used in these experiments. The rooms were identical except in one, the air was enriched with CO_2. The gas was dispersed through a perforated plastic pipe, by a flow meter from a cylinder of CO_2. In each experiment, 100 to 150 cuttings were placed in flats of sand covered with glass. One corner was left open to allow air circulation. The CO_2 was kept at 1800 to 2000 ppm during the illumination period of 12 hours daily. Chrysanthemum cuttings were treated with indole-3-butyric acid at 1000 ppm and the potentilla and weigela with 3000 ppm. The chrysanthemum cuttings were lifted after two weeks and the weigela and potentilla cuttings after four weeks. The number of roots per cutting were counted and their length was measured.

Mist Frames:

(a) *Greenhouse experiments* — In the greenhouse experiments, two identical frames were constructed; 2½ m long, 1 m wide and 60 cm high without covers. In one of them, the cuttings were misted with tap water and in the other with carbonated water. The CO_2 was added in a small mixing chamber made from a 3½ by 10 cm copper pipe. Both the water and CO_2 were controlled by solenoid valves, misting every 15 to 30 minutes for 20 seconds, depending on the rate of evaporation in the greenhouse. The CO_2 concentration of the tap water was 200 to 350 ppm and 1500-1800 ppm in the carbonated water, depending upon the temperature of the water. The rooting medium was perlite. The basal temperature was kept at 20-21°C with heating cables and the frames received supplementary light 12 hours per day. The light intensity was 20,000-21,000 Lumen/m^2 (1800 to 2000 foot candles).

(b) *Outdoor experiments* — In the outdoor experiments, we used two identical propagating beds; 16 m long, 1 m wide with 50 cm high sides without covers, but shaded only with snow fence. The rooting medium was sand. The carbonated mist set up was identical to the one in the greenhouse, except no heating cables were used at the bottom of the beds and the cuttings did not receive supplementary light.

The chrysanthemum cuttings were treated with indole-3-butyric acid at 1000 ppm and the softwood and evergreen cuttings with 3000 ppm. Potentilla and chrysanthemum cuttings were lifted after two weeks; softwood and conifer cuttings after 4-8 weeks. The number of roots per cutting were counted and their length was measured. Potentilla and chrysanthemum cuttings were weighed before inserting and again after lifting.

RESULTS:

Controlled Environment:

In the growth rooms, the atmosphere enriched with CO_2 significantly increased the rooting percentage and produced more roots per cutting (Table 1). It also significantly increased the dry weight of roots of chrysanthemum.

Table 1 Effect of CO_2 Enriched Atmosphere on Rooting of Cuttings

	Rooting period (weeks)	% Rooted		Av No of roots	
		CO_2	Check	CO_2	Check
Chrysanthemum '6408'	2	90*	77	13 4*	7 4
Weigela 'Centennial'	4	70**	46	18 0	3 0
Potentilla fruticosa 'Coronation Triumph'	4	77*	72	30 6**	13 2

* Differs from the check at P = 05
** Differs from the check at P = 01

Mist Frames

The greenhouse exeperiments with potentilla and chrysanthemum showed that no significant differences in rooting percentage occurred between the check and the CO_2 treatment, but the cutting rooted in carbonated water mist had more roots per cutting and they showed a much greater gain in weight the chrysanthemum cuttings grew about 2.5 cm more in the CO_2 than in the check.

Cuttings of evergreens also rooted better in carbonated mist. The first roots appeared on *Juniperus horizontalis* 'Dunvegan Blue' cuttings after two weeks. Mist of carbonated water increased the rooting percentage and produced more roots per cutting. *Juniperus horizontalis* 'Prince of Wales' responded similarly (Table 2).

Thuja occidentalis 'Brandon Pyramidal' and 'Globosa' showed higher rooting percentages in carbonated mist and more and larger roots per cutting than in the check (Table 2).

Table 2 Effect of Carbonated Mist on Rooting of Cuttings Indoors

	Rooting period (weeks)	% Rooted		% wt. gain		Av No of roots	
		CO_2	Check	CO_2	Check	CO_2	Check
Juniperus horizontalis							
'Dunvegan Blue'	5	88**	33	5 3	1 1	—	—
'Prince of Wales'	8	69**	48	3 1	2 1	—	—
Thuja occidentalis							
'Brandon Pyramidal'	8	72*	68	7 5	5.2	—	—
Potentilla fruticosa							
'Coronation Triumph'	2	99	97	—	—	129**	89
Chrysanthemum '6408'	2	100	97	—	—	113**	73

* Differs from the check at P = 05
** Differs from the check at P = 01

Thuja occidentalis 'Robusta' also showed higher rooting percentage in carbonated mist, but the total number of roots in the check plants exceeded those rooted in carbonated mist.

In the outdoor mist experiments, the carbonated mist also appeared to be beneficial for rooting of cuttings.

Cuttings of weigela rooted better in carbonated mist and had twice as many roots per cuttings compared to the check.

Juniperus horizontalis 'Dunvegan Blue, and 'Prince of Wales' have shown similar responses as in the greenhouse.

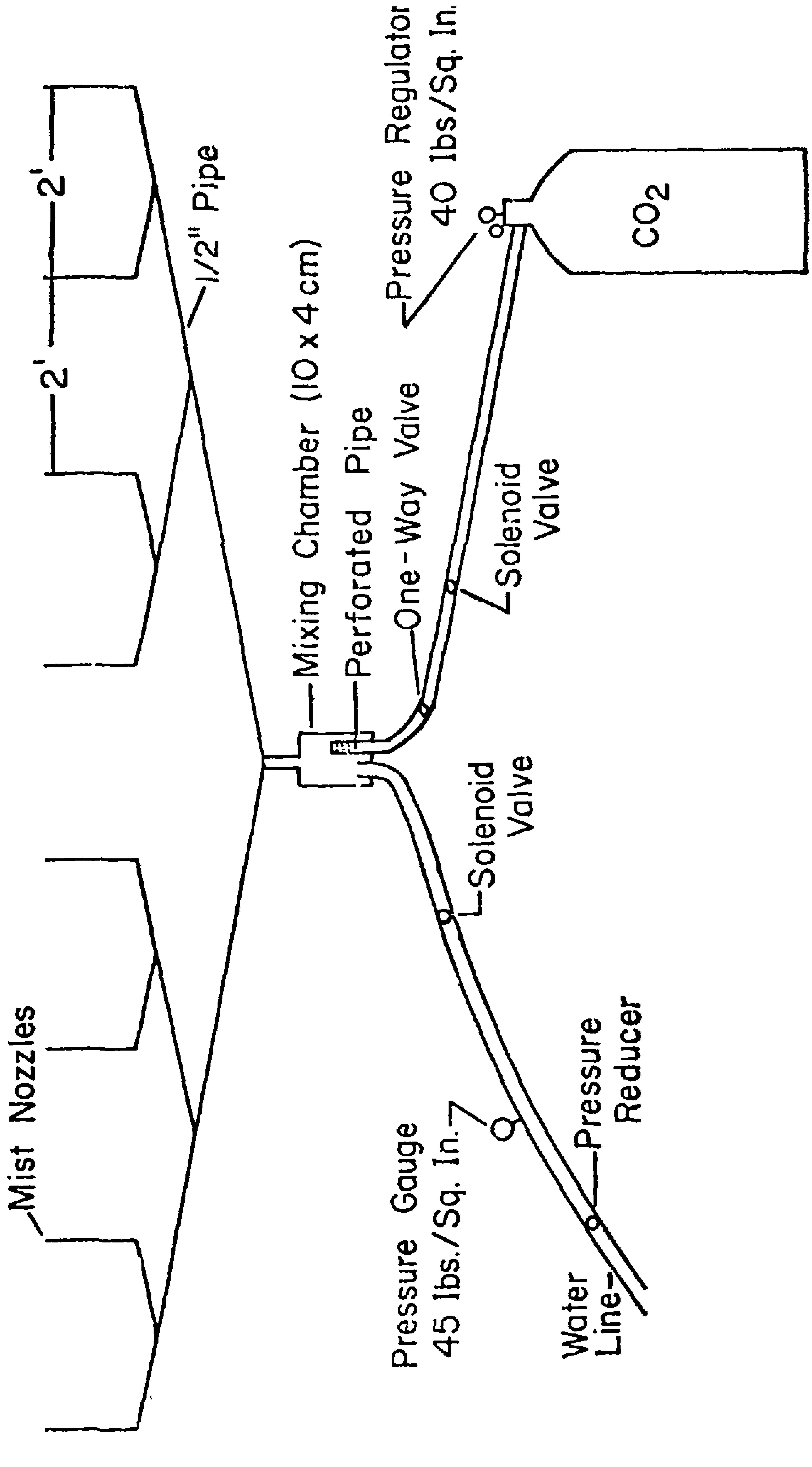
Lonicera tatarica 'Arnold Red' responded well to carbonated mist and not just increased the rooting percentage, but also the cuttings had more roots compared to the check.

Table 3. Effect of Carbonated Mist on Rooting of Cuttings Outdoors

	Rooting period (weeks)	% Rooted		Av No of roots	
		CO_2	Check	CO_2	Check
Weigela 'Centennial'	4	80*	69	10 6	5 2
'Dunvegan Blue'	5	76**	37	4 9	5 2
Lonicera tartarica					
'Arnold Red'	8	93**	52	9 4	3.9
Elaeagnus angustifolia					
'5501'	7	62	57	5 6**	2.2
Tilia cordata '6501'	8	53**	29	—	—

* Differs from the check at P = 05
** Differs from the check at P = 01

CO_2 MIST SET-UP



Elaeagnus angustifolia did not show a significant increase in rooting percentage in carbonated mist, but had more roots per cuttings and were generally in better condition after rooting. Cuttings rooted in carbonated mist hardly lost any leaves while cuttings in the check lost most of their leaves by the end of the rooting period.

Tillia cordata also rooted better in carbonated mist (Table 3).

DISCUSSION:

Cuttings stuck either in an atmosphere enriched with CO_2 or in carbonated mist showed improved rooting of the cuttings. The rooting percentage was higher in a number of plant species tested and root development was also better in most cases. These results are especially significant with evergreens which are normally hard to root.

Juniperus horizontalis rooted within a month, while it takes 2½ to 3 months to reach a similar or lower rooting percentage in ordinary mist frames. This could reduce the rooting time 50% in some cases.

Elaeagnus angustifolia while not showing a higher rooting percentage, produced better cuttings in carbonated mist.

The results with chrysanthemum and potentilla (where the cuttings gained 50% more weight in carbonated mist than in the check) also indicate that larger and more vigorous rooted cuttings are obtainable.

From the limited number of species tested to date in the carbonated mist it appears that certain species respond much better than others. These differences may be due to physiological or anatomical differences in the species. The stomatal size and number may cause the varying response of different species. For example, the stomata of African violets open wider when grown under mist and Scott (2) suggests that mist increases photosynthesis but reduces respiration and transpiration. Perhaps the stomata of plants which root better in carbonated mist open wider and if the photosynthesis is greater under mist, then the cuttings can use the additional CO_2 for growth and rooting.

The carbohydrate content has an effect on the rooting ability of cuttings, since they supply the energy and basic material for initiation and growth of roots. Since it is known that detached cuttings continue photosynthesising when inserted in the mist bench, and large leafy cuttings often produce the best plant in the shortest time, plant organs should grow faster when there is an increased rate of photosynthesis.

Another question is the manner in which plants obtain CO_2 from the mist. The possibility of its being absorbed in dissolved form from the water, or alternately, as gas after release from the water remains to be determined.

Comparing the results obtained in the greenhouse and outdoors — cuttings rooted somewhat better in the greenhouse experiment. These results may have been influenced by the fact that the temperature of the rooting medium was kept constant with heating cables and the light intensity was also kept at 1800 to 2000 foot candle. The CO_2 concentration of the water was approximately the same in the greenhouse and outside.

Last summer in Morden, the weather conditions were very unfavourable and the temperature of the rooting medium varied between 60 to 75°F and the light intensity was also very variable since the sky was overcast practically all summer. Therefore the temperature could have been a somewhat limiting factor in the outside experiments. However, it still proved that carbon dioxide is not limited only to greenhouse crops, since it can be used successfully in outdoor mist frames.

The best technique for applying the carbonated water and concentration still has to be determined, since our present equipment is far from satisfactory. If it is improved it could bring major benefits both in the economy of time and cost, in the production of plants from rooted cuttings.

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MODERATOR FORSTER: Thank you very much Joe. It is interesting to see such significant results from such a simple experiment.

VOICE: What time were your cuttings taken?

JOE MOLNAR: The cuttings were taken in the fall for the growth room experiments, while the cuttings for the other experiments were taken in the spring.

LLOYD RASWEILER: Do you know what percent of the CO_2 gets down to the medium.

JOE MOLNAR: I don't know but we did check the pH of the solution and know that it had little effect on the acidity.

LLOYD RASWEILER: What is the cost and do you think its benefits are sufficient to recommend it?

JOE MOLNAR: At the present time I would not recommend anyone to build such a set up but I do see possibilities for it, especially where plants are difficult to root otherwise or it takes them a much longer time to root.

HAROLD TUKEY: What was the purity of the CO_2.

JOE MOLNAR: I don't recall for sure but we encountered no problems from it, I think it was pretty pure.

DON KRIZEK: It appeared that your cuttings were rather yellow was this normal?

JOE MOLNAR: No, and I have been thinking that incorporating nutrients with the mist would overcome this but we have not done this yet.

MODERATOR FORSTER: I would like to introduce to you now, Dr. Phil Kozel who will speak on "Chemical Control of Plant Growth."

CHEMICAL CONTROL OF PLANT GROWTH

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We in horticulture are the potential beneficiary of a great deal of research being conducted in areas of biochemistry, chemistry, physics and plant physiology. Outstanding scientists, who are very often not plantsmen, have demonstrated that chemicals can profoundly effect plant growth. Today, for example, chemicals exist which can

— prevent, delay, or stimulate seed germiniation
— retard or accelerate vegetative growth
— increase or decrease lateral branching
— chemically prune plants (roots and shoots)
— prevent, delay, or accelerate flowering
— inhibit or promote fruit formation
— defoliate plants
— substitute for cold temperatures or long days etc., the list is very long

It is our responsibility in horticulture to be aware of the information gained from research in other areas of science and apply it to current needs of our industry. This concept is the essence of our plant growth regulator program at The Ohio State University.

One important concept must be understood concerning the use of chemicals to control plant growth. They are only a cultural tool for us to use, just like fertilizer and water. Chemicals can increase the quantity and quality of plant growth, but they will not substitute for poor cultural practices. In fact, best results will be attained only when the best possible cultural practices are already being followed.

I will present today some of the highlights of our work with growth regulators this past season. Our major goals in this program are to decrease the time it takes to produce salable size plants, increase plant quality, decrease labor costs and hopefully increase profits for the grower.

One phase of our study involved the testing of two growth retarding chemicals, B-Nine and Phosfon. B-Nine (N-dimethyl-