This morning we will consider several topics, the information of which has been or is being developed by research personnel in this state and in every other state in the Union. It is only a little over a score and ten years that we have begun to understand the nature of plant growth regulators and what they will do. And yet, in this short period of time, we have gone from a very infantile knowledge of plant growth regulators to the point where we cannot only say that we can control plant growth, but we can say that we can control it profitably and practically.

Our first speaker this morning is Peter Lert, who will discuss Plant Growth Made To Measure. Pete:

PLANT GROWTH MADE TO MEASURE

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Historically, man has always shown much interest in tailoring the growth of plants to his economical and aesthetic needs. All of our cultural measures, to some extent, involve tailoring plant growth — even if this only means the growing of larger and more vigorous plants. However, most people think in terms of regulating plant height when we talk about tailoring plants to measure.

At our meeting at San Dimas, California, in 1962, Dr. Harry Kohl presented a paper in which he pointed out that a variety of factors independently and interacting can influence plant height. These include genetic changes, clonal selection, pruning of tops or roots, light, temperature and moisture. But in this modern age of scientific marvels, people are less interested in some of these very effective but "old hat" ideas than in the use of chemical plant growth regulators.

While many chemicals may alter plant growth, including fertilizers, herbicides, auxins and kinins, it seems well to restrict today's discussion to gibberellins, growth retardants, and the growth inhibitor, maleic hydrazide.

So much has been said and written about the discovery and development of the gibberellins that it seems superfluous to say much about them at this time. However, for a better understanding of the mode of action of growth retardants, it is necessary to remember that gibberellins occur naturally in all plants and are responsible in part for the mechanism of elongation. Strangely enough, this particular aspect of gibberellins has not found too much practical application in commercial horticulture. However, other influences on flowering and fruiting have been developed to improve quality or time of maturity. Our moderator for this panel, Dr. Furuta, demonstrated that high rates of gibberellic acid could be substituted for the cold treatment, which is normally needed for the flowering of azaleas. Early flowering of *Camellia japonica* can also be induced with massive application of GA. Cluster formation and berry size of grapes, and maturity of lemons and limes can also be influenced, and may result in substantial economic gains for the grower.

Work done by Dr. Mark Cathey at the U.S.D.A. Station at Beltsville, Maryland, and by myself in California, demonstrated that it is possible to improve the shape of the spray of certain cultivars of pompon chrysanthemums by elongating the flower stalk. Unfortunately — or perhaps fortunately — the plant breeders since then have eliminated the necessity for this treatment in pompon chrysanthemums by developing cultivars which have naturally satisfactory spray shape and to the best of my knowledge, no use is made of gibberellins in chrysanthemum production at this time. Dr. Vernon Stoutemeyer has recently used GA to improve the linear growth of carob tree seedlings.

Development of growth retardants began in 1948 with the discovery at Beltsville that certain nicotinium compounds could retard the growth of bean plants without adversely affecting flowering, fruiting, or other normal growth mechanisms. In 1950 it was discovered that certain quaternary ammonium compounds retarded growth more effectively and on a wider range of plants. The best known of these compounds was designated as AMO-1618. However, its high price and effectiveness on a narrow range of plants limited its commercial use. Next came the development of the material designated as Phosfon, a material which is still being used at this time as a commercial growth retardant on chrysanthemums. Next on the scene was Cycocel, or CCC, which is currently being used on poinsettias, azaleas and to dwarf carnations for use as a pot plant. The latest o fthe currently available materials is B-Nine (B-995), which appears to be effective on a wide range of plants. One of its features is the fact that it can be sprayed rather than requiring soil application; another is its low rate of phytotoxicity. Commercial uses at this time include applications to chrysanthemums, hydrangeas, poinsettias and numerous annuals being used as bedding plants. Undoubtedly, additional compouds may be developed in the next few years, and wider uses found for those now on the market.

The most notable feature of this group of growth retardants is that they reduce the length of internodes without substantially inhibiting the development of leaves, flowers and fruits. Additional effects may include a deeper green color of the leaves, increased resistance to water stress, some resistance to air pollution and soil salinity and, in some cases, an increase in winter hardiness. The shortening of internodes is often accompanied by an increase in stem diameter. Precocious flowering is induced in some species, including fruit trees; and bud counts may be increased in azaleas.

In order to extend the usefulness of growth retardants, it is important to understand something about their basic action. Stem elongation takes place in the sub-apical meristem tissue (the area immediately behind the terminal growing point), and it is here that the growth retardants are most effective by reducing the number of cell divisions and the amount of cell expansion taking place. The apical meristem itself is relatively unaffected and continues to produce leaves and flowers more or less normally. The action of the retardants appears to be based on a mechanism which is antagonistic to the naturally occurring gibberellins in the plants, and in most cases it has been possible to reverse the action of retardants by applying GA and vice versa. In looking at plants which respond well to the presently available growth regulators, it seems that the majority of them are plants which in one way or another are day length or photoperiod responsive in either their growth or flowering habits.

Effectiveness of growth regulators can vary considerably depending on such factors as available light intensity, duration of photoperiod, temperature and, in the case of soil — applied materials, the growing medium. In the case of spray applications, the formulation of the material and the selection of the proper surfactent may influence its absorption; and it may well be that the lack of response of some of the woody species is due to failure to obtain proper absorption of the retardant. Generally speaking, the greatest percentage of growth retardation is obtained under conditions of maximum elongation.

So far, I have carefully skirted the special case of the growth inhibitor, maleic hydrazide. Unlike the growth retardants, it is most effective in the apical meristem tissue and inhibits the development of new leaves and additional shoots once it has been applied. It actually stops cell division and perhaps should be better classified as a herbicide. Nevertheless, it seems to have found some application as a substitute for pruning certain ground covers, shrubs and trees. However, the rather limited amount of work done so far indicates that the tolerance between effective control of growth and phytotoxicity is extremely narrow, and widespread side effects often accompany the inhibition of plant growth.

Indications are that we will see the development of more growth retardants and that we will learn ways of making far better use of the ones we already have. After all, it is only in recent years that we are beginning to make optimum use of such an old material as 2,4-D. Undoubtedly, future research will explore in greater detail modifications other than retardation of linear growth such as the effects on flowering and fruiting, reduced moisture stress, smog tolerance, and others.

MODERATOR FURUTA: Thank you, Peter. We would like to focus for a little while now on a relatively new development — I don't know if you really want to call it new — but at least there has been a lot of emphasis on it the last few years — and that is the possibility of fertilizing plants by increasing the carbon dioxide content of the air; fertilization in, perhaps, a different form from that we are used to. Dr. Harry Kohl of the Department of Landscape Horticulture, University of California at Davis. Harry:

CARBON DIOXIDE FERTILIZATION

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The idea of carbon dioxide fertilization is not a new one. In 1913 the first attempt at commercial application was reported from Europe and for some 20 years thereafter a fairly large amount of work was reported in this field. However, the practice was not adopted most probably because of the presence of injurious contaminants in the carbon dioxide used although lack of good control was also a problem and the limitations on its use were not understood.

In the mid 1950's the practice was revived largely because of the findings of Goldsberry at Colorado State University with carnations and has remained as a controversial, ill-understood practice since that time. A summary of a carbon dioxide survey made by Kennard Nelson in 1964 indicated that 1,478,600 sq. ft. under glass, almost all of which was in the northern tier of states, was receiving some added carbon dioxide. In the same summary a brief report of research work on flower crops by workers at six universities indicated mixed results. About half the findings showed significant gains (10% to 100%) from carbon dioxide fertilization. The other half showed essentially no gain. Only one reported a lower production by carbon dioxide fertilized plants.

Such varied results — even on the same crop — would seem to indicate that we should be thoroughly familiar with what carbon dioxide can and cannot do if a wise decision on if, as, when and how to use it is to be made. Presenting this necessary background is the reason for this paper.

Growth Efficiency

For most ornamental and vegetable crops the production is, grossly, the fresh weight of the crop produced. The amount of fresh weight produced per unit area per unit time is a measurement of the efficiency of production. But for each unit of fresh weight produced there is a minimum dry weight if the crop is of acceptable quality. In a sense then the good grower can be defined as one who can cause the plant to produce the maximum amount of fresh weight of acceptable quality from a given amount of dry weight. Temperature, water relations, mineral nutrition and photoperiod play primary roles here, not carbon dioxide, and hence if production is being re-