AIR-LAYERING WITH COLORED POLYETHYLENE FILM AND PLANT GROWTH REGULATORS

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AND PLANT GROWTH REGULATORS

By

FRANCIS F. T. CHING

AN ABSTRACT

Submitted to the College of Agriculture of Michigan

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FRANCIS CHING

ABSTRACT

Though previous workers have obtained favorable root formation in air-layering with colored polyethylene film and growth regulators, few workers have made an attempt to grow the new plants after they were severed from the parent plant. An attempt was made to determine the most suitable and practical methods for rooting and removing air-layers for further development of the new plant.

When rose plants were air-layered with naphthaleneacetic acid at 100 p.p.m., the greatest amount of root formation was produced. Though these roots were short and stubby, they all produced heavy root growth after they were severed from the parent plant and potted. Subsequent top growth of the cuttings after transplanting revealed that there was a difference in the degree of top growth, as well as root growth, depending upon the concentration of naphthaleneacetic acid used.

Naphthaleneacetic acid was not effective in promoting root growth at the concentrations used in the rooting media of air-layers of tomato plants. Though maleic hydrazide inhibited root growth at the concentrations used, the development of root formation was not affected.

Treatment of geranium plants with naphthaleneacetic acid was not effective in promoting root formation. However, the highest percentage of rooted plants occurred when the plants were grown under a continuous photoperiod.

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INTRODUCTION

The art of air-layering, as a means of propagation, has been known in China (16) for many centuries. Air-layering has received new impetus within the last ten years due to the development of plastic films which will maintain moisture and allow for suitable exchange of gases when used as wraps around a rooting media.

In 1947, Grove (8) used "Pliofilm" and later, "Vitafilm" for air-layering of the Lychee (*Litchi chinensis*). Air-layering with polyethylene film was later reported by Wyman in 1951 (23) and Creech in 1954 (4).

Though Wyman (23) obtained some very favorable results from his methods of air-layering, he made no attempt to solve the problem of cutting the potential plants from the parent and getting them to grow after they were potted. His few attempts to pot these plants were unsuccessful and he suggested that a further study should be made to determine the best methods of severing and potting the new plants for further development.

A further advance in the art of air-layering has been the introduction of growth promoting hormones as an aid in rooting. Using Hormodin No. 3, in which indolebutyric acid is the active ingredient, Wyman (23) indicated that in some cases, excess amounts may have been applied causing a hormone injury. Other workers (17) have found that growth promoting hormones are of little value in stimulating root initiation with air-layers.

With these difficulties in mind, an attempt was made to determine the most suitable and practical methods for rooting and removing the air-layer for further development of the new plant.

REVIEW OF THE LITERATURE

In the "Power of Movement of Plants", Darwin (5) wrote that this movement was caused by phototropism and geotropism.

The theory of Sachs, as reviewed by Went and Thimann (22), was that specific chemical substances influenced organ development as they moved from one part of the plant to the other.

Van der Lek, according to Went and Thimann (22), concluded that root formation was dependent somewhat upon the presence of sprouting buds although some roots could be formed without the presence of buds. He assumed that a growth substance was formed in the buds and transported downward to the basal portion of the cutting.

In 1905, animal physiologists introduced the word "Hormone", a Greek word meaning "Activity Arouser", a substance that is produced in one part of the body and translocated to other parts of the body by means of the blood stream. The word "Auxin", from another Greek word "To Increase", was later applied to synthetic substances which induced hormone-like responses when applied to plants.

Carbon monoxide, ethylene and other unsaturated hydro-carbon gases induce many responses in common with other plant hormones (25) and were recognized as physiologically active compounds before hormones were recognized. Though the chemical structures of these compounds are very different, the effects are similar. This fact lent support to the assumption that growth substances do not act directly but enter into complicated interactions with natural substances to produce a given result.

Fitting and Boysen-Jensen in 1910, according to a review (25), recognized that curvatures of shoots due to phototropism and geotropism involved an influence of a chemical nature. Paal (25), in 1918, showed that the growth of a certain plant organ is controlled by its tips. These discoveries led to the quantitative determinations of "growth substances" by bio-assay methods.

Since then, many synthetic substances have been found that will induce cell elongation or enlargement and many different methods have been devised for the application of these substances. In 1935, Hitchcock (11) described the activity of 3-indole propionic acid, and in the same year, Zimmerman and Wilcoxon (27) discussed some chemical growth substances which caused initiation of roots. Substituted phenoxy and benzoic acids were added to the list of growth substances by Zimmerman and Hitchcock (26) in 1942. These two groups of substituted acids marked the beginning of a new phase of plant hormone research by scientists all over the world. With this discovery, many new growth substances have been synthesized.

Plant hormones give very different results on various plants, and furthermore, give different results when used in various concentrations. Also, growth regulators produce different types of root systems (24). Indole compounds usually produce a more fibrous root system than alpha naphthaleneacetic acid (NAA), and in addition, indolebutyric acid does not inhibit the growth of terminal buds as much as NAA.

The discovery that indoleacetic acid was an excellent root-forming substance led to its practical use in the rooting of cuttings (1). Cooper (3) used a mixture of lanolin and indoleacetic acid. Hitchcock and Zimmerman (12) used a solution of crystalline acids, soaking the cuttings for a number of hours. A hormone powder, followed later by a "quick dip" method of a concentrated solution, was developed by Hitchcock and Zimmerman (13). Methods of applying plant hormones are reviewed by Stoutemyer (20). These methods include the powder preparations, the concentrated solution dipping method, and the prolonged soaking of cuttings in dilute solutions.

Ferri (6) found that synthetic growth substances applied as solutions to the soil of potted tomato and cleome plants can be absorbed and transported upwards in amounts sufficient to induce root formation on leaf cuttings sometime after treatment. Ferri also found that the upward movement of growth substances is independent of the activity of living cells. When growth substances were applied to the killed bases of tomato cuttings, the leaf cuttings above the treated areas were still able to produce roots.

Though root inducing substances are used by commercial propagators and amateurs, the total sales volume is not very great. Because these substances are very effective at very low concentrations, the same solutions or mixtures may be used over and over again. Basal portions of cuttings of tomatoes may be rooted in a water solution of indolebutyric acid of 1 p.p.m. and grape cuttings in an 80 p.p.m. solution. Some species root better as greenwood cuttings while others do better as hardwood cuttings.

Zimmerman, in a review (24), has discussed some of the uses of hormones. With the use of a variety of hormones, seedless tomatoes, eggplants, cucumbers, and squash may now be produced.

In an attempt to use growth promoting hormones to induce ovaries to develop into fruit without pollination, Gustafson (9), in 1936, was the first to produce seedless fruit of tomatoes, petunias, salpiglossus, and peppers by artificial methods.

Marth (14), using a-naphthylmethylacetate for treatment of rose bushes to prolong the dormant period in common storage, found that a vapor is most effective when applied to plants fully matured when stored. Shoot growth was also inhibited on immature plants but the effective period after treatment was of shorter duration and plants were more susceptible to injury as a result of treatment than were more mature plants.

Dormancy of evergreen fruit trees may be induced with sprays containing sodium naphthalene acetate (18). When used on lychee, maturation of vegetative terminals is hastened and further growth is prevented thus giving rise to most favorable conditions for development of flower inflorescence.

Alpha naphthaleneacetic acid (NAA), when properly applied, can inhibit buds, induce roots on cuttings and prevent abscission layers from forming. After treatment with NAA, potatoes can be stored for a long period of time without sprouting or shrinkage and fruit trees can be prevented from flowering. Flowering of ornamental shrubs can be delayed and the pre-harvest drop of apples may be prevented. Merlich (15), using NAA and other hormones in various concentrations, has found that an advance or delay in the time of differentiation of flowering may be controlled in the pineapple plant. He was also able to delay maturation and ripening from one week to two months, increase weight and size of fruit, and obtain a more desirable peduncle that is larger, stronger and more fibrous.

Air-layering is a method of propagating difficult-to-root and/or stiffly-erect plants. Where plants are naturally difficult to root by cuttings, mound and tip-layering is practiced. However, some plants are not adapted to mound or tip-layering, but are adapted to air-layering. A plant propagated by air-layering will be a genotype of the parent plant. By this method of propagation, branches, many times longer than a cutting may be rooted.

In 1947, Grove (8) used a type of plastic as a wrap to air-layer lychee and subsequently, received a patent for his process.

In 1951, Wyman (23) described properties of polyethylene film showing its permeability to gases and its moisture holding capacities. Wyman also used a root inducing substance as an aid to rooting and obtained some very good results on rooting. He did not pursue the problem any further as the operation of growing rooted plants was considered beyond the scope of his experiments.

Creech (4), in 1954, experimented with air-layering and carried his experiments further to include subsequent growth of new plants after they had been severed from the mother plant and also fertilized the stock plant while root formation was taking place. Immediate defoliation of leaves of the new plants took place when transplanted to peat. Both Wyman and Creech have been cognizant of the fact that even though the subsequent new plants form a substantial amount of roots, they may not survive transplanting.

Storey (19) has suggested that different colors of plastic film may produce a different effect on formation of roots.

Besides the use of plastic films and hormones, methods of air-layering have remained basically the same (2,4,7,10,17,21). A stem or branch, not more than two inches in diameter, is either notched or girdled and a rooting media such as moist sphagnum moss is placed around the scored area. Next, a wrapping or tie of some sort is applied to hold the rooting media in place. During the time of root formation, the rooting media must be kept moist until roots are observed and the new plant severed from the mother plant.

MATERIALS AND METHODS

PRELIMINARY STUDIES

Preliminary experiments were tried on the Rosa hybrida, var. Queen Elizabeth. Stems, approximately one-quarter inch in diameter and not more than a year old, were scored by the complete girdling technique in which a ring of bark, approximately one-quarter inch wide, was removed and a handful of sphagnum moss, which was soaked overnight, was squeezed of excess moisture and applied around the girdled area of the stem. A polyethylene film six inches square was then secured around the moss and the ends of the film affixed to the stem above and below the moss by means of "Twist-Ems'", Figure 1.

Four weeks after air-layering, the canes were severed below the girdled area and it was observed that although there was good callus formation, there was no visible root formation.

The cuttings were then uniformly decapitated leaving two nodes above the girdled area and, in addition, one-half the remaining leaves of each cutting were removed. The cuttings were then transplanted to four-inch clay pots containing a potting soil. Axillary buds began to grow by the end of the first week. After the third week, however, the cuttings had lost the remaining portion of their mature leaves and after five weeks, most of the cuttings were dead.

Figure 1. Air-layering of Rosa hybrida, var. Queen Elizabeth with colored polyethylene film.

AIR-LAYERING OF *ROSA HYBRIDA*, VAR. QUEEN ELIZABETH, USING VARIOUS CONCENTRATIONS OF ALPHA NAPHTHALENEACETIC ACID WITH COLORED POLYETHYLENE FILM

Since preliminary trials of air-layering *Rosa hybrida*, var. Queen Elizabeth, indicated that this plant was relatively difficult to root by ordinary air-layering methods, this variety was chosen for the first series of experiments. The experimental roses were obtained from plants growing on greenhouse benches at the Plant Science Greenhouse, Michigan State University, East Lansing, Michigan. Polyethylene film, .0015 inches in thickness, was obtained from the Bakelite Company in two different colors, black and white. Whereas previous workers applied a root inducing hormone to the scored area in the form of a dust or in a lanolin mixture, NAA was incorporated into the rooting media, sphagnum moss, by soaking the moss overnight in different concentrations of NAA. By this method of application, NAA would remain in constant contact and concentration with the scored portion of the stem than if a dust or lanolin mixture were used. The concentrations of 10 p.p.m. and 100 p.p.m. NAA were prepared by first dissolving the chemical in 95% ethyl alcohol and then diluting by adding tap water. The sphagnum moss was soaked overnight in either tap water or in solutions of NAA. The air wraps were secured at the ends by tying with four-inch "Twist-Ems'" as in the preliminary experiments. Scoring, method of application and type of stem used were the same as used in the preliminary experiments.

There were twelve replications for each of the six variables for a total of seventy-two treatments.

After the plants had been layered for two weeks, it was noticed that there was a difference in temperatures between layers wrapped with white film and those wrapped with the black film. In order to determine the temperature fluctuations, thermometers were inserted into the air-layers and temperatures recorded at noon of each day.

After six weeks, the layers were removed by severing the stem below the girdled area and the amount of rooting and callusing was recorded. The stems were then decapitated to two nodes above the girdled area and one-half the remaining leaves of each cutting were removed. The individual cuttings were then transplanted to four-inch clay pots using a potting soil. In addition, fresh non air-layered cuttings of the same variety were planted in the same manner in order to observe the formation of roots by this method. The amount of growth made by axillary buds was recorded each week. Four weeks after transplanting, the roots were washed and the root growth was recorded. The plants that were treated with 100 p.p.m. NAA and the plants that formed only a heavy callus with 10 p.p.m. NAA, were divided into two groups; a few plants of each treatment were washed at the end of four weeks and the remainder were washed eight weeks after transplanting.

AIR-LAYERING OF LYCOPERSICON ESCULENTUM, VAR. COMMUNE, MICHIGAN-OHIO, USING VARIOUS CONCENTRATIONS OF NAA UNDER DIFFERENT PHOTOPERIODS

Seeds of the Michigan-Ohio Hybrid variety of tomatoes were sown in a flat November 19, 1955 and were transplanted to eight-inch clay pots four weeks later. Two weeks before air-layering, one-half the potted plants were placed under continuous light supplied by four 40-watt white florescent bulbs. These plants remained under these lights for the duration of the experiment while the other plants remained under a normal day-length.

The tomato stem was scored by removing the sixth leaf above the cotyledon and a cut was made into the stem thus removing a portion of the stem that extended into the region of the xylem.

White polyethylene film of .0015 inches thick was used as wraps and the ends were secured with four-inch "Twist-Ems'".

Concentrations of NAA and method of application of the rooting media were the same as used with the roses.

There were fourteen replications for each of six variables for a total of eighty-four treatments. In addition, each variable was divided so that one-half the plants were air-layered for two weeks and the other one-half were air-layered for three weeks.

Two and three weeks after treatment, the air-layers were removed by severing the plants below the girdled area and amount of rooting was recorded. The cuttings were then decapitated to two nodes above the girdled area and the cuttings defoliated. The plants were then transplanted into eight-inch clay pots and returned to their respective photoperiod. A nutrient solution containing 10-6-4 fertilizer was applied to the new plants the second week after transplanting. The amount of growth made by the axillary buds was recorded for each week and at the end of the fourth week the roots were washed and amount of root growth was recorded.

AIR-LAYERING OF *PELARGONIUM ZONALE*, VAR. RADIO RED, USING VARIOUS CONCENTRATIONS OF NAA AND DIFFERENT PHOTOPERIODS

Potted *Pelargonium zonale*, var. Radio Red plants, approximately six months old, were used.

The stems were scored four inches below the terminal point of growth by removing a portion of the stem one-quarter inch long and one-eighth inch wide on opposite sides of the stem.

White polyethylene film .0015 inches thick was used as wraps and the ends were secured with four-inch "Twist-Ems'".

Concentrations of NAA and the control, and the method of application were the same as used with the roses.

Previous to air-layering, one-half the plants were placed under continuous light for one week. The light was supplied by four 40-watt white flourescent bulbs.

There were five replications for each of six variables for a total of thirty treatments. In addition, an attempt was made to root cuttings in sand under a normal day-length.

Four weeks after air-layering, the wrappings were removed and amount of root formation was recorded.

AIR-LAYERING OF *LYCOPERSICON ESCULENTUM*, VAR. COMMUNE, SPARTAN HYBRID, USING VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE

Ten week old plants of the Spartan Hybrid variety of tomatoes were used for this experiment. Sphagnum moss was soaked overnight in tap water and in solutions of 5 p.p.m. and 50 p.p.m. of maleic hydrazide. White polyethylene film of .0015 inches in thickness was used for wraps. Methods of scoring and application of the sphagnum moss were the same as previously used with the treatment of tomato plants using NAA. No photoperiod was involved in this experiment. There were seven treatments for each of three variables. At the end of two weeks, the wrappings were removed and amount of root formation was recorded.

RESULTS

AIR-LAYERING OF *ROSA HYBRIDA*, VAR. QUEEN ELIZABETH, USING VARIOUS CONCENTRATIONS OF ALPHA NAPHTHALENEACETIC ACID WITH COLORED POLYETHYLENE FILM

Various concentrations of NAA produced different types of root formation. Root growth and top growth after transplanting indicated that different concentrations of NAA had a residual effect on plants as to the type of growth that was produced.

It was found that rooting and callusing was heavy when air-layers were treated with NAA as compared to controls, Tables I and II. When air-layers were applied with 10 p.p.m. NAA, one-half the air-layers produced a moderate amount of roots which were long and slender with a small amount of branch roots, Figure 2. Treatment with NAA at 100 p.p.m. increased the percentage of air-layers showing heavy root formation, although the roots were very short and stubby which indicated that NAA at this concentration may seriously inhibit subsequent root growth, Figure 3.

There were considerable differences in amount of root growth after air-layered plants were transplanted and allowed to grow for four and eight weeks, Tables III and IV. Plants that had formed roots when air-layered with 10 p.p.m. NAA produced considerable root growth four weeks after transplanting. Cuttings which had formed a heavy root growth when air-layered also produced the heaviest amount of root growth when transplanted, Figure 4. These roots were fibrous and branched. Of the roots that were present after being transplanted for four weeks,

Figure 2. Root and callus formation on air-layers of <u>Rosa hybrida</u>, var. Queen Elizabeth in relation to different treatments with NAA. Left, 100 p.p.m. NAA. Center, 10 p.p.m. NAA. Right, control.

Figure 3. Root formation of <u>Rosa hybrida</u>, var. Queen Elizabeth, when air-layered with 100 p.p.m. NAA.

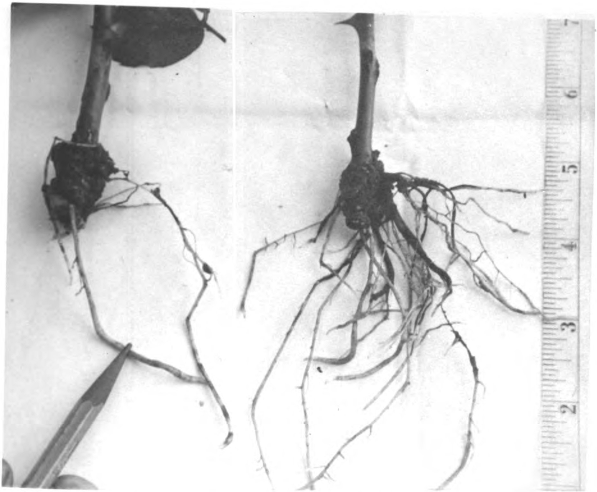

Figure 4. Root growth of Rosa hybrida, var. Queen Elizabeth, four weeks after transplanting in relation to root formation when air-layered with 10 p.p.m. NAA. Left, moderate root formation when transplanted. Right, heavy root formation when transplanted.

TABLE I

The Effect of Different Concentrations of NAA and Colored Polyethylene Wraps on Rooting of Air-layers of *Rosa hybrida*, var. Queen Elizabeth

Color of Polyethylene	Concentration of NAA	Amount of Roots Formed[1]			
		None	Light	Medium	Heavy
Black	Control	91.7%	8.3%	.0%	.0%
	10 p.p.m.	50.0%	.0%	41.7%	8.3%
	100 p.p.m.	8.3%	.0%	.0%	91.7%
White	Control	100.0%	.0%	.0%	.0%
	10 p.p.m.	50.0%	.0%	41.7%	8.3%
	100 p.p.m.	.0%	.0%	.0%	100.0%

1. Degree of rooting was a subjective estimate from 12 cuttings in each treatment.

TABLE II

The Effect of Different Concentrations of NAA and Colored Polyethylene on Callus Formation of Air-layers of *Rosa hybrida*, var. Queen Elizabeth

Color of Polyethylene	Concentration of NAA	Amount of Callus Formed[1]		
		Light	Medium	Heavy
	Control	33.3%	66.7%	.0%
Black	10 p.p.m.	.0%	.0%	100.0%
	100 p.p.m.	.0%	.0%	100.0%
	Control	33.3%	66.7%	.0%
White	10 p.p.m.	.0%	.0%	100.0%
	100 p.p.m.	.0%	.0%	100.0%

1. Degree of callusing was a subjective estimate of 12 cuttings in each treatment.

TABLE III

The Percentage of Root Growth Four Weeks After Air-layered Cuttings, As Compared With Non Air-layered Cuttings of <u>Rosa hybrida</u>, var. Queen Elizabeth, Were Transplanted

Condition of Cuttings at Time of Transplanting	Amount of Root Growth*			
	None	Light	Medium	Heavy
Non Air-layered Cuttings**	87.5	12.5	.0	.0
Air-layered at 10 p.p.m. with Roots**	.0	.0	75.0	25.0
Air-layered at 10 p.p.m. with Callus Only***	33.3	66.7	.0	.0
Air-layered at 100 p.p.m. with Roots***	.0	.0	.0	100.0

* Degree of root growth was a subjective estimate.
** Eight cuttings per treatment
*** Three cuttings per treatment

TABLE IV

Percent Root Growth Eight Weeks After Air-layers of *Rosa hybrida*, Var. Queen Elizabeth, Were Transplanted

Condition of Cuttings at Time of Transplanting	Amount of Root Growth[1]		
	Light	Medium	Heavy
10 p.p.m. NAA with Callus Only	60.0	40.0	.0
100 p.p.m. NAA with Roots	.0	.0	100.0

1. Degree of root growth was a subjective estimate from 6 cuttings in each treatment.

approximately one-fourth were dead. There was also a new callus formation at the basal end of the stem.

Plants that had formed very short stubby roots when air-layered with 100 p.p.m. NAA produced heavy root growth four weeks after transplanting, Figure 5. Although root growth was heavy, there were no branch roots. After eight weeks, these same plants produced a very heavy root growth and in a few cases, top growth. Where top growth was present, there was a development of fibrous roots which indicated that there was a correlation between top growth and type of root formation, Figure 6.

Plants with only a callus, formed under the air-layer treatment with NAA at 10 p.p.m. developed a light to moderate amount of roots eight weeks after transplanting. A new callused area formed at the basal end of these cuttings and it was from this area that most of the roots originated. Roots were of non-fibrous type.

Non-air-layered cuttings, planted in pots, were examined after four weeks. With one exception, all of these cuttings were without any visible roots.

Average height of axillary bud growth after transplanting was recorded, Table V. Shoot growth of non-air-layered cuttings developed immediately. By the end of the fourth week, most of these plants had lost their mature leaves and by the end of the fifth week, most plants were dead or dying, presumably due to lack of water and nutrient absorption.

Cuttings, which developed long, slender and fibrous roots when air-layered with 10 p.p.m. of NAA, were initially slow to develop new shoot growth. After seven days, however, top growth exceeded that made

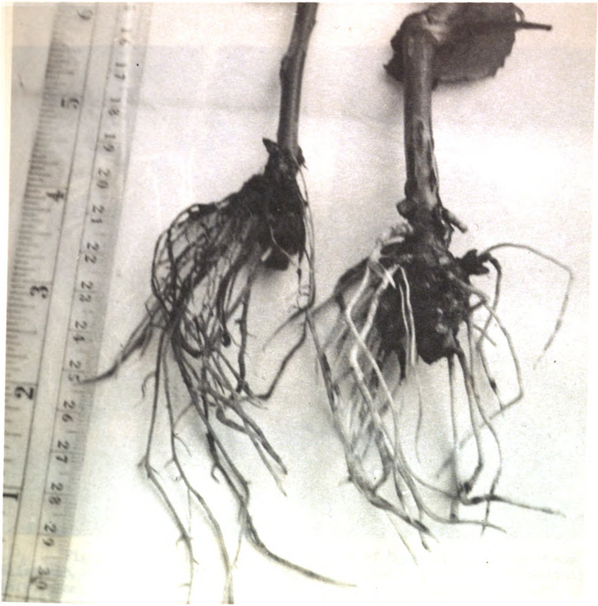

Figure 5. Root growth of Rosa hybrida, var. Queen Elizabeth, four weeks after transplanting in relation to different treatments with NAA when air-layered. Left, 10 p.p.m. NAA. Right, 100 p.p.m. NAA.

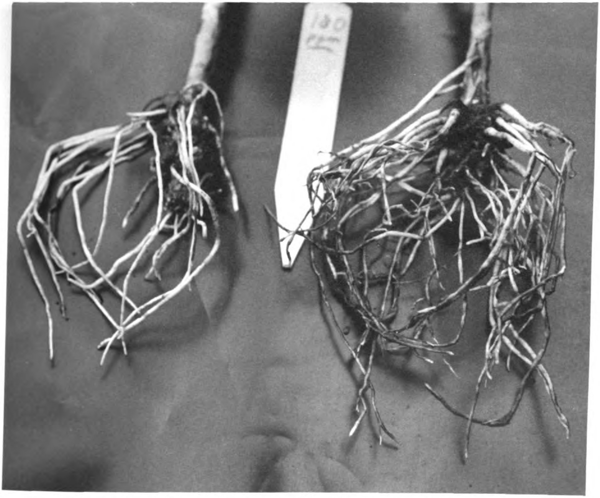

Figure 6. Variations in root growth of Rosa hybrida, var. Queen Elizabeth, air-layered with 100 p.p.m. NAA. Eight weeks after transplanting. Left, plant with no branch roots and no top growth. Right, plant with branch roots and top growth.

TABLE V

Average Height, in Centimeters, of Axil Bud Growth of Air-layers of *Rosa hybrida*, var. Queen Elizabeth, After Transplanting

Weeks After Transplanting	Condition of Cuttings at Time of Transplanting		
	Non air-layered	Air-layered with NAA	
	Cuttings	10 p.p.m.	100 p.p.m.
	No Roots[1]	Fibrous Roots[2]	Stubby Roots[3]
1st Week	1.0	.5	
2nd "	2.3	2.8	
3rd "	3.0	5.8	
4th "	5.0	7.8	
5th "			----
6th "			2.8
7th "			3.3
8th "			3.8

1. Average of 8 plants.

2. Average of 7 plants.

3. Average of 3 plants.

by non-air-layered cuttings. Most top growth was made by plants that had heaviest root growth. By the end of five weeks, some of these plants had lost all of their mature leaves.

All cuttings, which were air-layered with 10 p.p.m. NAA and which formed only a callus, with one exception, did not form any top growth. The reason shoots did not develop could have been due to lack of roots which thus caused a deficiency in the accumulation of nutrients and food material required for growth. Although root initials may have been present in the callused area, the callus may have hardened when the cuttings were transplanted. It is also possible that the NAA may have inhibited the shoots.

Four weeks after transplanting, three of the plants that had been air-layered with 100 p.p.m. of NAA produced top growth, although all plants had produced a heavy root growth. Eight weeks after transplanting, where there was top growth, branch roots were present. Results of this experiment indicated that air-layering with 100 p.p.m. of NAA will inhibit shoot growth, but not root growth, after transplanting. Furthermore, eight weeks after plants were air-layered with 100 p.p.m. NAA, all cuttings retained their mature leaves thus emphasizing the fact that NAA will prevent formation of an abscission layer and may also give added life to the leaf.

The use of different colors of polyethylene in air-layering apparently had no effect on formation of roots, although there was a difference in temperatures of the air-layers, Table VI and VII.

On sunny to partially sunny days, the air-layers with black polyethylene film produced highest temperatures. While a maximum

TABLE VI

Room and Internal Temperatures (in Fahrenheit) of Air-layers of *Rosa hybrida*, var. Queen Elizabeth, on Sunny to Partially Sunny Days.

	Sunny Side of Rose Bench			Shady Side of Rose Bench		
	Color of Polyethylene			Color of Polyethylene		
	Black	White	Air Temperature	Black	White	Air Temperature
	89.6	82.4	77.0	77.0	66.2	74.0
	89.6	80.6	73.0	73.4	65.4	75.0
	91.4	82.4	75.0	77.0	69.9	79.9
	86.0	76.8	75.0	77.0	68.0	77.0
	86.0	78.8	75.0	77.0	68.0	75.0
	78.8	75.2	79.0	80.6	66.2	75.0
	96.8	89.6	79.0	71.6	60.8	75.0
	93.2	86.0	80.0	80.6	63.4	79.0
	87.8	80.6	77.0	78.8	71.6	80.0
	87.0	78.0	75.0			
Avg. Temp.	88.6	81.0	76.5	77.0	67.7	76.7

TABLE VII

Room and Internal Temperatures (in Fahrenheit) of Air-layers of Rosa hybrida, var. Queen Elizabeth, on Cloudy to Partially Sunny Days.

	Sunny Side of Rose Bench			Shady Side of Rose Bench		
	Color of Polyethylene			Color of Polyethylene		
	Black	White	Air Temperature	Black	White	Air Temperature
	69.8	66.2	68.0	69.8	64.4	65.0
	77.0	7.16	72.0	68.0	62.6	67.0
	69.8	68.0	68.0			
	80.6	75.2	70.0			
	69.8	68.0	66.0			
	69.8	66.2	66.0			
	71.8	68.0	64.0			
	69.8	68.0	65.0			
	69.8	68.0	67.0			
	82.4	77.0	74.0			
Avg. Temp.	73.1	69.6	68.0	68.9	63.5	66.0

temperature of 96.8° F. was recorded with plants air-layered with black polyethylene film on the sunny side of the bench, the highest room temperature attained was 80.0° F. High temperature when white polyethylene was used for wraps of air-layers on the sunny side of the rose bench was 89.6° F.

On sunny to partially sunny days, but on the shady side of the rose bench, the air-layers with the black polyethylene had only a slightly higher temperature than the room temperature while temperatures of the air-layers with white polyethylene were always lower than the room temperature.

On cloudy to partially sunny days, the fluctuation in temperature, between the shady and sunny sides of the rose bench with the different colors of polyethylene, was at a minimum.

This study on roses has indicated that the methods and materials used in air-layering are favorable to the propagation of plants that are difficult-to-root. Use of NAA in concentrations of 100 p.p.m., though it appeared to be detrimental at first, was in many respects, beneficial. After a plant is air-layered, severed from the original plant and transplanted, it is desirable that top growth remain inactive while the roots have an opportunity to develop. NAA at 100 p.p.m. will inhibit shoot growth without any inhibiting effect on root growth.

The type of root formation produced, when rose plants were air-layered with 100 p.p.m. of NAA, may be most desirable. When the newly formed plant is transplanted, the sphagnum moss may be removed without damage or breakage to the roots. By removing the sphagnum moss, all roots will be in direct contact with the soil for further growth and optimum conditions for nutrient uptake. Furthermore, NAA at concentrations of 100 p.p.m. prevented fall of mature leaves.

There were no apparent differences on root formation between black and white polyethylene when used for wraps of air-layers. However, the lower temperatures recorded when white polyethylene was used for wraps indicated that this color of polyethylene may be most favorable to use. Most air-layering is practiced in the spring and summer when air temperatures are high with strong light intensities. As the maximum temperature for optimum root formation is approximately 85° F., white polyethylene will keep the internal temperatures of air-layers to a minimum.

AIR-LAYERING OF *LYCOPERSICON ESCULENTUM*, VAR. COMMUNE, MICHIGAN X OHIO USING VARIOUS CONCENTRATIONS OF NAA UNDER DIFFERENT PHOTOPERIODS

When tomato stems were air-layered with white polyethylene and treated with different photoperiods and concentrations of NAA, various amounts of roots were produced, Tables VIII and IX. After transplanting, the different photoperiods and concentrations of NAA also affected subsequent root and top growth.

When tomato stems were air-layered for two and three weeks under a normal day length and treated with 10 p.p.m. NAA, rooting occurred and was more pronounced when air-layered for three weeks, Figure 7.

Tomato stems air-layered for two and three weeks with 100 p.p.m. NAA and placed under a normal day length developed only short, stubby roots or root initials.

TABLE VIII

Effect of Different Photoperiods and Various Concentrations of NAA on Root Formation[1] of Two-Week Air-layers of *Lycopersicon esculentum*, var. Commune, Michigan X Ohio.

Photoperiod	Control				10 p.p.m.				100 p.p.m.			
	Root Initials	Light	Medium	Heavy	Root Initials	Light	Medium	Heavy	Root Initials	Light	Medium	Heavy
Normal Day Length	.0%	.0%	.0%	100.0%	.0%	.0%	100.0%	.0%	100.0%	.0%	.0%	.0%
Continuous	.0%	.0%	.0%	100.0%	.0%	.0%	100.0%	.0%	100.0%	.0%	.0%	.0%

1. Degree of root formation was a subjective estimate from 7 cuttings in each treatment.

TABLE IX

TABLE IX

Effect of Different Photoperiods and Various Concentrations of NAA on Root Formation[1] of Three-Week Air-layers of *Lycopersicon esculentum*, var. Commune, Michigan X Ohio.

Photoperiod	Control				10 p.p.m.				100 p.p.m.			
	Root Initials	Light	Medium	Heavy	Root Initials	Light	Medium	Heavy	Root Initials	Light	Medium	Heavy
Normal Day Length	.0%	.0%	.0%	100.0%	.0%	.0%	60.0%	40.0%	100.0%	.0%	.0%	.0%
Continuous	.0%	.0%	.0%	100.0%	.0%	.0%	60.0%	40.0%	100.0%	.0%	.0%	.0%

1. Degree of root formation was a subjective estimate from 7 cuttings in each treatment.

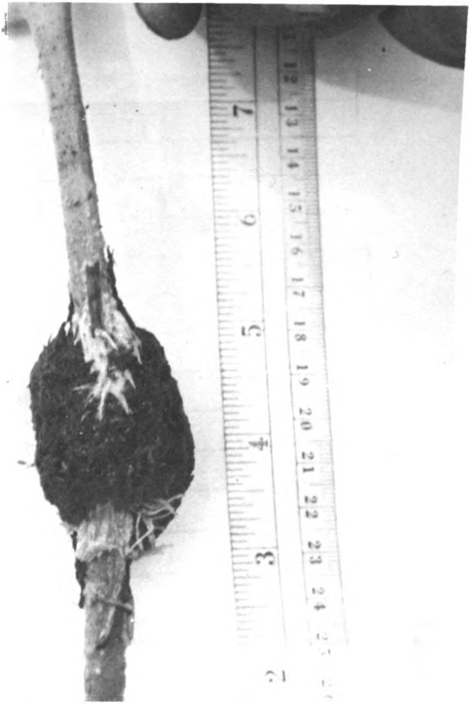

Figure 7. Moderate root formation of Lycopersicon esculentum, var. commune, Michigan X Ohio, when air-layered with 10 p.p.m. NAA under a normal day length for two weeks.

Figure 8. Heavy root formation of Lycopersicon esculentum, var. commune, Michigan X Ohio, when air-layered for two weeks under a normal day length and without NAA.

Tomato stems air-layered for two and three weeks and placed under a normal day-length without an application of NAA produced a heavy formation of roots, Figure 8. It was also noticed that the sphagnum moss of these air-layers was dry when the air-layers were removed, thus indicating that newly formed roots are proficient in uptake of water.

Air-layering of tomato plants for two and three weeks under a continuous photoperiod and with different concentrations of NAA produced similar results as when other tomato plants were air-layered under a normal day length with the same concentrations of NAA, Tables VIII and IX.

As all two and three-week air-layers that had not been treated with NAA produced a heavier root formation than air-layers that had been treated with NAA, this served to emphasize the fact that plants respond differently when treated with a root inducing hormone.

Symptoms of physiological disturbance appeared on leaves of tomato plants three days after the air-layers were applied to the stems of the tomato plants.

Symptoms first appeared as small necrotic spots on various leaflets of the leaf followed by chlorosis and complete wilting of the leaflet affected. Symptoms usually appeared on the second and third leaf above the girdled area and in a few cases, also appeared on the first, fourth and fifth leaf above the girdled area. Symptoms appeared in 13.6% of the plants that were not treated with NAA and placed under a normal day-length and again in 13.6% of plants that were not treated with NAA and placed under a continuous photoperiod. None of the plants treated with 10 p.p.m. NAA were affected. With plants that were air-layered with 100 p.p.m. NAA, symptoms appeared in 64.3% of plants that were under a normal day-length and in 92.8% of plants that were under a continuous photoperiod.

It was thought that these symptoms may be signs of a nutrient deficiency due to scoring as the plants had previously produced signs of a nitrogen deficiency. Thus, three plants of the same variety and age were scored in the previously described manner, but no air-layer was applied; symptoms did not appear. Three additional plants were air-layered with 100 p.p.m. NAA and again symptoms appeared.

Cause of the damage that developed from air-layering remains unexplained. However, there were indications that concentrations of NAA at 100 p.p.m. will accentuate the symptoms while NAA at 10 p.p.m. may, in some way, compensate or offset occurrence of symptoms.

Four weeks after two and three-week air-layers were transplanted, the different air-layering treatments produced different amounts of top growth, Tables X and XI and Figure 9.

Variations in top growth produced by two-week air-layers under different photoperiods and NAA treatments indicated that a combination of a long photoperiod with NAA in a low concentration, such as 10 p.p.m. will produce a physiological effect on axillary buds causing them to sprout and grow at a faster rate than normal.

Four weeks after transplanting, 50% of the two-week air-layers treated with 100 p.p.m. NAA and placed under a normal and continuous photoperiod were just beginning to produce top growth while the remaining plants were dead or dying. An examination of these plants revealed that the stem of the cutting in vicinity of the notched area had deteriorated and root formation and growth was taking place above and

TABLE X

Average Height in Centimeters of Axil Bud Growth[1] of Lycopersicon esculentum, var. Commune, Michigan X Ohio, After Transplanting of Two-Week Air-layers That Were Treated With Various Concentrations of NAA and Different Photoperiods.

	Condition of Cuttings at Time of Transplanting					
	Normal Day Length			Continuous Light		
Weeks After Transplanting	Control Heavy Rooting	10 p.p.m. Moderate Rooting	100 p.p.m. Root Initials Only	Control Heavy Rooting	10 p.p.m. Moderate Rooting	100 p.p.m. Root Initials Only
2nd Week	4.5	3.0	.0	5.0	4.0	.0
3rd "	9.3	8.3	.0	13.0	14.3	.0
4th "	10.8	10.3	.0	16.0	19.5	.0

1. Average height based on 7 cuttings in each treatment.

Figure 9. Top growth of two-week air-layers of Lycopersicon esculentum, var. commune, Michigan X Ohio, plants in relation to different treatments with NAA two weeks after transplanting. Left, control. Center, 10 p.p.m. NAA. Right, 100 p.p.m. NAA.

below this area.

Four weeks after transplanting, all three-week air-layers treated with 100 p.p.m. NAA and placed under a normal and continuous photoperiod produced two centimeters of top growth. An examination of these plants revealed that the stems had not deteriorated and that a moderate amount of roots were present.

Three-week air-layers that were grown under a normal photoperiod and were not treated with NAA produced about four centimeters more top growth four weeks after transplanting than did two-week air-layers grown under a normal photoperiod and not treated with NAA.

Four weeks after transplanting, plants air-layered for three-weeks, treated with 10 p.p.m. of NAA and placed under a normal photoperiod produced two centimeters more top growth than did two-week air-layers treated with 10 p.p.m. NAA and placed under a normal photoperiod. However, these three-week air-layers treated with NAA produced less top growth than three-week air-layers that were not treated with NAA.

Three-week air-layers under a continuous photoperiod and treated with 10 p.p.m. NAA produced approximately four centimeters less top growth than did two-week air-layers placed under a continuous photoperiod and treated with 10 p.p.m. NAA. Three-week air-layers that received a continuous photoperiod but not treated with NAA also produced approximately three centimeters less top growth than did two-week air-layers treated in the same manner.

As with two-week air-layers that received a continuous photoperiod, four weeks after transplanting, the three-week air-layers treated with 10 p.p.m. and placed under a continuous photoperiod produced approximately three centimeters more top growth than did three-week air-layers treated with 10 p.p.m. of NAA and placed under a normal photoperiod.

Four weeks after the two and three-week air-layers were transplanted, the different air-layering treatments produced different amounts of root growth, Tables XII and XIII.

All plants that were air-layered for two weeks, except those treated with 100 p.p.m. NAA produced a heavy root growth four weeks after transplanting. Likewise, all plants air-layered for three weeks, except those treated with 100 p.p.m. NAA, produced a heavy root growth four weeks after they were transplanted. However, root growth was of a heavier type in three-week air-layers than in two-week air-layers. Formation of a slightly heavier amount of root growth by plants air-layered for three weeks may be due to a more mature root system at time of transplanting.

AIR-LAYERING OF *PELARGONIUM ZONALE*, VAR. RADIO RED USING VARIOUS CONCENTRATIONS OF NAA UNDER DIFFERENT PHOTOPERIODS

Four weeks after treatment, air-layers that received different concentrations of NAA along with cuttings placed in sand produced different amounts of root formation, Table XIV.

Of cuttings placed in sand under a normal photoperiod, 20% rooted while another 13% were dead or dying. An examination of dead and dying plants revealed that the portion of the plant that had been placed in sand had rotted away.

Forty percent of the plants not treated with NAA and grown under a normal photoperiod produced roots while another 20% were dead or dying. All dead or dying plants revealed the same symptoms upon examination;

Table XII

Percentage Root Growth Four Weeks After Three-Week Air-layers of <u>Lycopersicon esculentum</u>, Var. Commune, Michigan X Ohio, Were Transplanted.

Type of Root Growth[1]		Normal Day Length			Continuous Light	
	Control	10 p.p.m.	100 p.p.m.	Control	10 p.p.m.	100 p.p.m.
Light	.0%	.0%	85.7%	.0%	.0%	71.4%
Medium	.0%	.0%	14.3%	.0%	.0%	28.6%
Heavy	100.0%	100.0%	.0%	100.0%	100.0%	.0%

1. Degree of root growth was a subjective estimate of 7 plants in each treatment.

TABLE XIII

Percentage Root Growth Four Weeks After Two-Week Air-layers of _Lycopersicon esculentum_, Var. Commune, Michigan X Ohio, Were Transplanted.

Type of Root Growth[1]	Normal Day Length			Continuous Light		
	Control	10 p.p.m.	100 p.p.m.	Control	10 p.p.m.	100 p.p.m.
Light	.0%	.0%	66.7%	.0%	.0%	50.0%
Medium	.0%	.0%	33.3%	.0%	.0%	50.0%
Heavy	100.0%	100.0%	.0%	100.0%	100.0%	.0%

1. Degree of root growth was a subjective estimate of 7 plants in each treatment.

TABLE XIV

Effect of Different Photoperiods and Various Concentrations of NAA on Root Growth[1] of Air-layers of *Pelargonium zonale*, Var. Radio Red.

Light Treatment	Treatment to Stems	No Roots Formed	Light Rooting	Moderate Rooting	Heavy Rooting	Stems Dead
	Cuttings in Sand	66.7%	13.3%	.0%	6.7%	13.3%
Normal Day Length	Control	40.0%	.0%	40.0%	.0%	20.0%
	10 p.p.m.	20.0%	.0%	.0%	.0%	80.0%
	100 p.p.m.	.0%	.0%	.0%	.0%	100.0%
Continuous Light	Control	20.0%	.0%	60.0%	.0%	20.0%
	10 p.p.m.	.0%	60.0%	.0%	.0%	40.0%
	100 p.p.m.	.0%	.0%	.0%	.0%	100.0%

1. Degree of root formation was a subjective estimate of 5 cuttings in each treatment.

a progressive chlorosis of the leaves starting from where the air-layer was applied and progressing to the apical portion of the stem. The portion of the stem where the air-layer was applied had deteriorated as had the basal portions of the cuttings that were placed in sand.

As deterioration of the stems occurred with the cuttings placed in sand and also in the air-layers that were not treated with NAA, the immediate cause was probably due to pathogens and a high moisture content while concentrations of NAA from low to high accentuated the deterioration.

Though 20% of air-layers not treated with NAA and grown under a continuous photoperiod were dead or dying, 60% formed roots. Of the air-layers that were treated with 10 p.p.m. NAA, 60% formed roots, while 40% of the plants were dead or dying. All plants treated with 100 p.p.m. NAA were dead or dying four weeks after air-layering. Symptoms of dead or dying plants were the same as previously described.

Where root formation had taken place the sphagnum moss was in a dry condition while the moss was still very moist in air-layers where there was no root formation.

This experiment indicated that a longer day-length probably caused a faster top growth thus giving rise to faster root formation which undoubtedly caused the sphagnum moss to dry out. This would indicate, that with some plants, it would be best to air-layer in spring or summer when days are longer or when the plant is making maximum growth.

AIR-LAYERING OF *LYCOPERSICON ESCULENTUM*, VAR. COMMUNE, SPARTAN HYBRID WITH VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE

Two weeks after treatment, the air-layers that were not treated with maleic hydrazide produced the greatest amount of root growth, Table XV, Figure 10. Air-layers that were treated with 5 p.p.m. maleic hydrazide developed a moderate amount of root growth while air-layers that were treated with 50 p.p.m. maleic hydrazide produced very short roots or root initials.

Though maleic hydrazide tended to inhibit root growth, it did not prevent the formation of roots.

Figure 10. Root formation and growth of air-layers of Lycopersicon esculentum, var. commune, Spartan Hybrid, in relation to treatment with maleic hydrazide. Left, 5 p.p.m. maleic hydrazide. Right, control.

TABLE XV

Percentage Root Growth When Various Concentrations of Maleic Hybrazide Were Applied to the Air-layers of *Lycopersicon esculentum*, Var. Commune, Spartan Hybrid.

Treatment	Type of Root Growth[1]			
	Root Initials Only	Light	Medium	Heavy
Control	.0%	.0%	14.3%	85.7%
5 p.p.m.	.0%	33.3%	66.7%	.0%
50 p.p.m.	25.0%	75.0%	.0%	.0%

1. The amount of root growth was a subjective estimate of 7 plants in each treatment.

SUMMARY

An attempt was made to determine the most suitable and practical method for rooting and removing air-layers from plants using growth regulators and colored polyethylene film as aids in rooting.

I. A. When _Rosa hybrida_, var. Queen Elizabeth plants were air-layered with NAA, it was found that a concentration of 100 p.p.m. was most suitable for the greatest root formation.

B. Plants air-layered with NAA at 10 p.p.m. produced long, slender roots compared with short, stubby roots when treated at 100 p.p.m.

C. Subsequent growth of the cuttings after transplanting revealed that there was a difference in the degree of both top and root growth depending on the concentration of NAA used.

II. A. When _Lycopersicon esculentum_, var. commune, Michigan X Ohio plants were air-layered with NAA in the rooting media, it was found that at the concentrations used, the growth regulator was not effective in promoting root growth.

B. It was observed that under certain conditions air-layering in the tomato produced symptoms of a physiological disturbance in the plant. This reaction was not apparent when NAA was used at 10 p.p.m. in the rooting media.

III. When _Pelargonium zonale_, var. Radio Red plants were air-layered with NAA, in the rooting media, under various photoperiods it was found that the highest percentage of rooted plants occurred when the plants were grown under a continuous photoperiod. Treatment with NAA was not effective in the promotion of root initials.

IV. When Lycopersicon esculentum, var. commune, Spartan Hybrid plants were air-layered using maleic hydrazide in the rooting media, it was found that root growth was inhibited at both 5 and 50 p.p.m. The development of root initials were not affected, however.

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