On the program there are many firsts, in other words, the first time these various topics have been presented. This morning we have three professors on the program presenting three of these new topics.

Our first speaker this morning, Donald White, is a graduate of the University of Massachusetts in ornamental horticulture, and who now is taking his graduate work at Iowa State. This will be a report of five years work in the development of dwarfing understock for budding and grafting both ornamental and fruit plants.

We are most unfortunate in not having Mr. White with us since he was called back to Massachusetts because of the death of his father We have John Mahlstede who will read his paper, and I am sure will be able to answer any questions regarding this work. John Mahlstede!

DR. JOHN MAHLSTEDE (Iowa State University, Ames, Iowa): Mr. Moderator, President Templeton, and Members of the Plant Propagators Society:

This paper is entitled, "Compatibility in Grafting and Budding Fruit and Ornamental Plants for Adaptation and Dwarfing Purposes." This was the topic we have selected for discussion this morning.

COMPATIBILITY IN GRAFTING AND BUDDING FRUIT AND ORNAMENTAL PLANTS FOR ADAPTATION AND DWARFING PURPOSES[1]

D. B. WHITE and J. P. MAHLSTEDE
Department of Horticulture
Iowa State University
Ames, Iowa

This is the first progress report on a project initiated at Iowa State University in 1956 entitled "Dwarfing of Fruit and Ornamental Plants." One of the primary objectives of this project is the development of techniques for dwarfing and adapting ornamental plants to different soil or climatic conditions. Many select plant materials, normally tall growing, would be well suited for use with modern contemporary building designs if height development could be restricted. Since this project was initiated, several stations have reported on similar work which is either underway or in the planning stage. The number of projects reaffirms the need for an increased inventory of low growing plant materials having acceptable ornamental characteristics, for areas differing in soil and climatic conditions.

One of the most common problems encountered in grafting is that of incompatibility. This inability of two components when grafted together to produce a healthy plant has been known for many centuries. In the third century B.C., Cato (4) observed that the scion used in grafting should always be of a better type than the rootstock, and that certain combinations could not be made successfully. Many other writers of his day reorded similar experiences with the practice of grafting. Francis Bacon, (2), in 1639 stated that a diversity of fruit could be

[1]Journal Paper No. J-4101 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No 1310

grown on one tree but that all of the scions must be compatible with the stock. Miller, (10) 1759, described double working pear and quince when the pear to be dwarfed was uncongenial with the quince. Thomas Andrew Knight (8), reported some of the symptoms of incompatibility and compared them with the effects caused by girdling.

Work during the past decade with apples, arborvitae, cotoneaster, forsythia, hawthorn, junipers, maples, pyracantha, quince and viburnum (Sax 14, 15, 16, 17, 18; Chadwick 5; Strate and Barker 19; Reisch et al 12) has demonstrated some of the possibilities for the development of dwarf plant materials by the use of selected understocks. However, in all of these studies incompatibility appears to be the one factor restricting the use of dwarfing stocks only to those types which have been tested.

There are many definitions for the term compatibility. In general, compatibility may be considered to be the ability of a grafted combination to survive for the period necessary for its use. This appears to be quite satisfactory since both inherited antagonisms and acquired agents are given consideration. Environmental factors and the techniques used in grafting also are very important to an understanding of compatibility in grafted plants. Recently, workers have found that on certain plants, bud failure can be attributed to virus infection (Milbrath and Zeller 9; Overholzer 11.) Agrios (1) reported virus-like symptoms with combinations of peach on *Prunus tomentosa* and *Prunus besseyi*. However, this work revealed that viruses were not involved, and bud failure was ascribed to incompatibility. Much of the work to date further emphasizes the need for caution in interpreting results of compatibility studies, considering that many factors may influence or result in incompatibility.

Left: Prunus Underwood on P. besseyi, 1½ years from bud, compared to a 12″ label.

Right: P. Sacagawea (cherry x plum) on P. besseyi, 1½ years from bud, compared to 12″ label.

For the past three years many different combinations have been under trial at Iowa State University. Some of these were not original but were included solely as a means of reference. This work was undertaken mainly as a screening program which might form the basis for further experimentation. After selecting plant materials for testing, the major problem became that of finding compatible combinations. As there is no rule or method of predicting the performance of a graft combination (Bradford and Sitton 3; Roberts 13), the plant materials were selected by separating them according to botanical relationships and chromosome number. The technique of budding was employed in these first screening tests because it is fast and economical of wood. It precludes the problems of purchasing and maintaining large numbers of plants while requiring a minimum of hired labor. Budding is eminently suited for this type of testing, as demonstrated by its use as the basic technique for indexing virus diseases.

One must realize that these tests cover a relatively short period of time. Consequently, final results can be secured only by observation over a number of years. Many of the combinations which were unsuccessful with budding will be repeated using other techniques and different timing of the procedure.

BIBLIOGRAPHY

1 Agrios, George N Virus-like symptoms on year-old peach trees propagated on *Prunus tomentosa* and *Prunus besseyi* rootstocks Unpublished Ph D Thesis Ames, Iowa, Library, Iowa State University of Science and Technology 1960

2 Bacon Francis Sylva Sylvarum or a Natural History Fifth edition John Haviland, London 1639

3 Bradford, F. C. and B G. Sitton Defective graft unions in the apple and pear. Tech Bul No 99 Mich St Col, 1929

4. Cato, the Censor On farming Translated by Ernest Brehaut New York, New York, Columbia, U Press 1933

5 Chadwick, L C The influence of several understocks on the growth of scions of some varieties of juniper Amer Soc Hort Sci 58 301-307 1951

6 Darlington, C D and E K Janaki Ammal Chromosome atlas of cultivated plants London G. Allen & Unwin Ltd 1945

7 Index to plant chromosomes Cal Bot Soc 1956-1959

8 Knight, Thomas Andrew. On the effects of different kinds of stocks on grafting Trans Hort Soc of London 2 199-204 1822

9. Milbrath, J A and S M. Zeller Latent viruses in stone fruits Sci 101: 114-115 1945

10 Miller, P The gardners dictionary Seventh edition London 1759

11. Overholzer, P G J The Bitter Seville rootstock problem Farming in South Africa 255· No 22 489-495 1947

12. Reisch, K W, L. C Chadwick and P A Barker Dwarfing stocks for woody ornamental plants Ohio. Farm and Home Res July-August 1958

13. Roberts, R H Theoretical aspects of graftage Bot Rev 15 No 7 1949

14. Sax, Karl Dwarf trees Arnoldia 10 No 12 Boston. November, 1950

15. ——— ———. Dwarf ornamental and fruit trees Proc Plant Prop Soc 146-155. November, 1957.

16 Sax, Karl Interstock effects in dwarfing fruit trees Proc Amer Soc Hort Sci 62 201-208 1953

17 ——— ——— Plant breeding at the Arnold Arboretum Arnoldia 15; No 2 Boston April, 1955

18 ——— ——— The control of vegetative growth and the induction of early fruiting in apple trees Proc Amer Soc Hort Sci 69 68-74 1957

19. Strate, J. E. and P A Barker A study of dwarfing medium and large shrubs and small trees Ohio Nurs. Assoc Report. 1954.

TABLE I

STOCK	CHROM NO	SCION	CHROM NO	DATE BUDDED	REMARKS
ACERACEAE					
Acer ginnala	26	Acer Crimson King	X=13	7/26/57	No take
Acer ginnala	26	Acer Crimson King	X=13	9/ 4/57	No take
Acer ginnala	26	Acer saccharinum	52	7/26/58	No take
Acer ginnala	26	A ginnala PI69112	26	3/29/57	(root graft) survived summer 1958, winter killed
Acer negundo	26	Acer Crimson King	X=13	7/25/58	Buds failed, plates knitted then died in 1½ months
Acer negundo	26	Acer Crimson King	X=13	7/25/59	Buds failed, plates knitted then died in 1½ months
Acer negundo	26	Acer saccharinum	52	7/25/58	No take
Acer negundo	26	Acer saccharinum	52	8/ 5/58	No take, plate seems to knit then dries up
Acer negundo	26	Acer saccharum	26	9/25/58	No take
Acer negundo	26	Acer saccharum	26	8/18/59	No take, buds too immature before late Aug - early Sept.
Acer saccharinum	52	Acer Crimson King	X=13	7/23/58	Stock overgrew & completely imbedded buds by Fall
Acer saccharinum	52	Acer saccharum	26	8/ 5/58	Stock overgrew & completely imbedded buds by Fall
Acer saccharinum	52	Acer saccharum	26	8/18/59	Buds seems to take, stock overgrew by Fall
Acer saccharinum	52	Acer saccharum	26	9/15/59	Buds seemed to take, failed next spring
ROSACEAE					
Amelanchier canadensis	68	Aronia melanocarpa	34	8/ 3/59	No take, stock not thrifty, hard to work
Amelanchier canadensis	68	Malus, Jonadel	X=17	8/11/58	Shields knitted, buds failed over winter, stock hard to work
Amelanchier canadensis	68	Malus, Jonadel	X=17	9/14/58	Shields knitted, buds failed over winter, stock hard to work
Amelanchier canadensis	68	Malus, Red Delicious	X=17	8/ 4/59	Shields took, buds failed over winter
Amelanchier canadensis	68	Pyrus, De Anjou	X=17	8/ 4/58	Shields took, buds failed over winter
Amelanchier canadensis	68	Pyrus, De Anjou	X=17	7/28/59	Shields took, buds failed over winter
Aronia melanocarpa	34	Amelanchier canadensis	68	8/ 3/59	Some degree of affinity, seem to take, failed over winter
Aronia melanocarpa	34	Malus, Jonadel	X=17	8/14/58	Plate took, buds failed over winter
Aronia melanocarpa	34	Malus, Red Delicious	34, 51	8/ 4/59	Buds take (weak union)
Aronia melanocarpa	34	Pyrus, Bartlett	X=17	8/16/58	1 bud break = 1" growth by 9/25/58
Aronia melanocarpa	34	Pyrus, Bartlett	X=17	8/16/60	½ of buds took, to be tenant grafted on apple

TABLE I (Continued)

STOCK	CHROM NO	SCION	CHROM NO	DATE BUDDED	REMARKS
Aronia melanocarpa	34	Pyrus, De Anjou	X=17	8/16/58	⅓ of buds took, others, shields took
Aronia melanocarpa	34	Pyrus, De Anjou	X=17	7/28/59	⅓ of buds took, others, shields took
Cotoneaster acutifolius	X—17	Amelanchier canadensis	68	8/ 3/59	Plates took and survive, buds dead, some plates later died
Cotoneaster acutifolia	X—17	Malus, Red Delicious	X=17	7/25/58	Plates took and survive, buds dead over winter
Cotoneaster acutifolia	X—17	Malus, Red Delicious	X=17	8/ 4/59	Plates took and survive, buds dead over winter
Cotoneaster acutifolia	X—17	Pyrus, Bartlett	X=17	8/16/58	Plates took, buds go out 1st then bud plates
Cotoneaster acutifolia	X—17	Pyrus DeAnjou	X=17	8/16/58	Plates took, buds dead
Cotoneaster acutifolia	X—17	Pyrus DeAnjou	X=17	7/28/59	Plates took, buds dead, plates raised by heavy callus
Crataegus cordata	72	Malus, Red Delicious	X=17	8/ 4/59	Plate knits, buds dead, stock overgrows plate, stock hard to work
Crataegus crus-galli	68	Malus, Red Delicious	X=17	8/ 4/59	Plate knits, buds dead, stock overgrows plate, stock hard to work
Crataegus oxyacantha	34	Malus, Red Delicious	X=17	8/ 4/59	Plates seem to knit, bud and plates dead, stock overgrown
Cydonia/DeAnjou Pear	X—17	Pyrus, Bartlett	34, 51, 68	9/ 4/59	87 7% take
Malus, seedlings (Wstrn)	X—17	Amelanchier canadensis	68	8/ 3/59	Plates seemed to take, buds & plates died
Malus, seedlings (Wstrn)	X—17	Pyronia veitchi		5/ 1/58	Root grafts, 100% take, tops winter kill badly
Phil coronarius nanus	X=13	Phil. coronarius	26	7/26/57	No take, very hard to work, thin, peeling bark, small stems
Phys opulifolius nanus	X=9	Physocarpus opulifolius	18	7/30/57	No take, very hard to work, thin, peeling, bark small stems
Prunus besseyi	16	Prunus, Chinook Plum	X=8	8/21/57	No take, although seemed to knit
Prunus besseyi	16	Prunus, Gracious Plum	X—28	8/21/57	No take, although seemed to knit
Prunus besseyi	16	Hiawatha (Cherry X Plum)	Unk	8/21/57	No take, although seemed to knit
Prunus besseyi	16	Prunus, Monitor	X=8	8/21/57	Take
Prunus besseyi	16	Prunus armeniaca Apricot	16	8/21/57	No take
Prunus besseyi	16	Prunus persica	16	8/24/59	No take
Prunus besseyi	16	Red Plum Ia No. 10	Unk	7/30/57	No take
Prunus besseyi	16	Sacagawea (Cherry X Plum)	Unk	8/21/57	Take
Prunus besseyi	16	Prunus, Underwood	X=8	7/30/57	Take
Prunus subhirtella pendula	16	Prunus (Red Haven Peach)	16	8/24/59	Seemed to knit, but no survival over winter
Prunus tomentosa	16	Monitor Plum	X=8	7/31/57	No take
Prunus tomentosa	16	Red Plum, Ia No 10	Unk	7/29/57	Buds took, most growth = 3′ in 2 years, all plants of this lot of P tomentosa died in 3d yr

continued on next page

TABLE 1 (continued)

STOCK	CHROM NO	SCION	CHROM NO	DATE BUDDED	REMARKS
Pyrus seedlings	X=17	*Amelanchier canadensis*	68	8/ 3/59	*No take, scion not thrifty*
Rhodotypos scandens	18	Kerria japonica	18	8/10/59	No take, gall-like callus, ⅜" thick around wound, stem breaks easily at point of budding
CAPRIFOLIACEAE					
Viburnum dentatum	54	Kolkwitzia amabilis	32	8/16/58	No take, scion difficult to work
Viburnum lantana	18	Wiegela Vaniceki	36	7/23/58	No take, Wiegela hard to work as bud
V opulus nana	X=9	Viburnum dentatum	54	7/29/57	No take
V opulus nana	X=9	Viburnum lentago	18	7/29/57	No take
V opulus nana	X=9	Viburnum opulus	18	7/26/57	Plate seems to knit, dies overwinter sloughed off the following year
CELASTRACEAE					
Celastrus scandens	46	Euonymus alatus	X=8	7/30/57	No take
Celastrus scandens	46	Euonymus alatus compacta	X=8	7/30/57	No take
Euonymus turkestanica	X=8	Euonymus alatus	X=8	7/26/57	(in greenhouse) seemed to take, then died, stock hard to work (small), suggest grafting
Euonymus turkestanica	X=8	Euonymus alatus compacta	X=8	7/26/57	(in greenhouse) seemed to take, then died, stock hard to work (small), suggest grafting
Euonymus turkestanica	X=8	Euonymus europaeus	64	7/26/57	(in greenhouse) seemed to take, then died, stock hard to work (small), suggest grafting
CORNACEAE					
Cornus stolonifera	X=10, 11	Cornus florida	X=10, 11	3/29/57	(whip & tongue grafts) both were alive but could get no callus to form
FAGACEAE					
Quercus palustris	24	Fagus sylvatica	24	7/23/58	Knitted Buds died over winter
Quercus palustris	24	Fagus sylvatica	24	9/15/59	Hard to work because of long pointed bud
LEGUMINOSAE					
Sophora japonica	X=9, 14	Maackia amurensis	Unk	3/29/57	(root grafts) Passed out during summer of 57
OLEACEAE					
Chionanthus virginicus	46	Fraxinus pennsylvanica	46	7/25/58	Plates took, buds probably too immature
Chionanthus virginicus	46	Fraxinus pennsylvanica	46	8/18/59	Plates took, buds failed by spring, plates still living
Forsythia Arnold's Dwarf	X=14	Forsythia suspensa	28	7/ 2/57	Apparent take, but no survival over winter
Forsythia Arnold's Dwarf	X=14	Forsythia suspensa	28	7/ 2/58	Apparent take, but no survival over winter

continued on next page

TABLE 1 (continued)

STOCK	CHROM NO	SCION	CHROM NO	DATE BUDDED	REMARKS
Forsythia Arnold's Dwarf	X=14	Forsythia suspensa	28	9/15/59	(shield & flute buds) few took, large callus around wounds where no take
Forsythia viridissima	28	F viridissima koreana	28	3/29/57	(root grafts) no take, plants survived a short while in planting bed
F. viridissima Bronxensis	X=14	Forsythia suspensa	26	7/ 2/57	No take
F. viridissima Bronxensis	X=14	Forsythia suspensa	26	7/ 2/58	No take
Fraxinus pennsylvanica	46	Chionanthus virginicus	46	7/24/58	Plates knitted, buds died
Fraxinus pennsylvanica	46	Chionanthus virginicus	46	8/18/59	Stock overgrew, plates the following year
Fraxinus pennsylvanica	46	Syringa villosa	46—48	7/24/58	
Ligustrum densiflora nana	X=23	Ligustrum amurense	46	7/26/57	No take, very hard to work, small stems
Syringa persica alba	44	Chionanthus virginicus	46	8/18/59	Plates took, died over winter
Syringa persica alba	44	Fraxinus pennsylvanica	46	7/25/58	Plates took, died over winter
Syringa persica alba	44	Fraxinus pennsylvanica	46	8/10/59	Take, buds still dormant, on stocks not cut back
Syringa persica alba	44	Syringa amurensis	46	7/30/57	Take buds still dormant. on stocks not cut back
Syringa rothomagensis	X—22	Syringa oblata dilatata	46	3/29/57	(root grafts), survived until late summer of '57
Syringa rothomagensis	X—23				
Syringa rothomagensis	X—24	#8994			
Syringa rothomagensis	X—24	Syringa oblata dilatata #9446	46	3/29/57	(root grafts), survived until late summer of '57
Syringa rothomagensis	X—24	Syringa oblata dilatata #9449	46	3/29/57	(root grafts), survived until late summer of '57
Syringa villosa	46—48	Chionanthus virginicus	46	8/18/59	Plate knitted and surviving buds dead
Syringa villosa	46—48	Fraxinus pennsylvanica	46	7/25/58	Plates took, 1 bud survived, grew to 3½' in '59, acted normal, died during winter of '59, strong union, overgrows stock
Syringa villosa	46—48	Fraxinus pennsylvanica	46	7/25/59	Plates knitted, buds dead
ULMACEAE					
Celtis occidentalis	20, 28	Ulmus americana	28, 56	7/25/58	Plates knit, buds fail by fall, or are overgrown and imbedded
Celtis occidentalis	20, 28	Ulmus americana	28, 56	9/15/59	Plates knit, buds fail by fall, or are overgrown and imbedded

MODERATOR NORDINE: You are to state your name clearly so Mrs Ely can get it, and then state your question Dr. McDaniel.

DR. JOSEPH C. McDANIEL (University of Illinois): My question doesn't deserve all that attention I want to ask what is the material that was grafted on hackberry stock?

DR. MAHLSTEDE *Ulmus americana* and a few buds of *Ulmus fulva*.

DR. McDANIEL: Any compatibility?

DR. MAHLSTEDE: The bud plates seemed to knit with the American elm, but were overgrown by the time growth stopped There was no take by *U fulva*.

MR. CASE HOOGENDOORN. (Newport, Rhode Island): Have you tried de-eyeing some of the shrubs before using them?

DR. MAHLSTEDE. Most of these are budded on seedlings or clumps which have not been dis-budded

MR. HOOGENDOORN: Why don't you start with a new cutting or seedling? If you start with a young seedling or rooted cutting you could pick the eyes out

Years ago we grafted lilacs on *Syringa vulgaris* I always used to de-eye the one-year seedlings which resulted in very little suckering I was interested in knowing if you couldn't apply that same technique.

DR. MAHLSTEDE: First, we were trying to see which ones we can bud in other words we were trying to test for compatibility After this some of these techniques such as the one you mentioned, Case can be used.

DR. STUART H. NELSON (Ottawa, Canada): John, do you have any explanation for the trouble we ran into? Where we bud we run into a lot of incompatibility, the same as you have shown Where we stub graft we don't run into the incompatibility at all and get excellent stands

DR. MAHLSTEDE: I can only venture a guess, Stu Many workers in the past have found that grafting gave better results than budding with some combinations This may be the result of the fact that a single bud has less chance, percentagewise than a scion with more than one bud and a greater area of cambium exposure. Viruses too, may play a greater role than we now realize

MR EDWARD DAVIS (Ozark Nursery Co., Tahlequah, Okla.): Did I understand in giving this paper that Buckholz had better stands with peach on *P. tomentosa* than on *P besseyi?*

DR. MAHLSTEDE· No, not necessarily They lost less trees on *P. tomentosa* after forcing the bud and during the following growing season. However, the initial take was much less.

MR DAVIS: We have tried *Prunus tomentosa* for about four years, and get from two to five per cent bud take On *P. besseyi*, we have a very good stand as high as 95 per cent on bud take However, there is a high per cent of die-back on *P. besseyi* after the bud start They die all summer and fall The question arises in my mind how long will the trees, we accept as being compatible and healthy, live? What are the chances there?

DR. MAHLSTEDE: Buckholz and Agrios had 45 per cent diseased trees on *P. besseyi* One customer sent back some six year old trees to one nursery that were broken at the union. I think our time is up.

MODERATOR NORDINE: Last year we had considerable discussion by a great many speakers in regard to the production of nursery stock or plants in containers. I am sure that a great many members felt that after that they knew all the answers. Fertilization of this material was, of course, stressed, but some way, somehow, someone overlooked the topic of over-fertilization.

We are very happy this morning to have Dr Jim Kelley of the University of Kentucky present this particular topic to you. He has spent a great deal of time and effort on solving some of the problems concerned with the production of nursery stock in cans At this time we present to you Dr. Kelley.

EFFECTS OF OVERFERTILIZATION ON CONTAINER-GROWN PLANTS

JAMES D. KELLEY
Department of Horticulture
University of Kentucky
Lexington, Kentucky

The widespread practice of growing nursery stock in containers has brought about a need for more information in regard to the fertility requirements of woody ornamental plants. Fertilization has always been important in growing quality nursery stock, however, fertilization assumes even greater importance when a plant is grown in a restricted volume of soil such as exists in a container. There are many unanswered questions concerning this type of culture One question that has been of great importance is the fertilization practices necessary for producing quality nursery stock in containers Little is known about the fertility requirements of woody ornamental plants. However, the limited volume of soil that is available for supplying the necessary nutrients of a plant in a container necessitates that for optimum growth, fertilizer be applied to supply the required plant nutrients.

REASON FOR FERTILIZATION

The purpose of fertilization is to provide the plant with a continuous supply and optimum level of plant nutrients for maximum growth of any particular species. Frequent fertilization has aided in providing a constant supply However, information is not available on the optimum levels that should be maintained for woody ornamental plants. Growers are naturally anxious to obtain the maximum growth on a plant whether in a container or in the field. Many times this desire to get rapid growth, particularly on container stock, has led to the application of unusually high amounts of fertilizer. Too much fertilizer, however, can be as bad or even worse than too little. Many times plants are overfertilized, resulting in a reduction in growth instead of more growth.