THE USE OF CUTTING-GRAFTS FOR PRODUCING GRAFTED JUNIPERS

by

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INTRODUCTION

Grafting has long been the standard method of propagating the clones of the Redcedar, Juniperus virginiana, and other species of the genus Juniperus. The usual method has been to graft a scion of the desired clone to a potted rootstock, but in experimental work by Keen (15) and Buckley (7) and by at least two commercial nurseries in Kansas, unrooted cuttings have been used as the rootstock for such grafts.

In the experiment here reported, some of the factors related to the feasability of commercial production of cutting-grafts were investigated. Rate of growth, compatibility, and survival of cutting-grafts were compared to that of grafts on potted Redcedar rootstocks. The most satisfactory time of year for making cutting-grafts was also studied.

REVIEW OF LITERATURE

Graft Defined

Bailey (2) defined grafting as, "The operation of inserting a bud or cion in a stock."

Kains (13) and Kains and McQuesten (14) described cutting-grafts as, "a union of a graft with a cutting." They stated that difficult to root species could be grafted, by this method, to a related species which roots easily.

Cutting-grafting was defined by Baltet (4) as "grafting on a stock which is a cutting." He described this method of propagation as the use of a cutting, with a few leaves attached, into the split top of which was inserted the desired scion.

Bailey (3) in addition to writing that cutting and grafting could be combined by grafting plants that root with difficulty to cuttings of easily rooted varieties, stated that, at the first transplanting of the plant thus produced, the stock could be removed if the scion had produced roots.

Adriance and Brison (1) reported that grafts made by grafting unrooted cuttings with a desired scion variety could either be stored until the graft had callused before planting in the field or planted directly into the field as soon as the grafting operation was completed.

History

As reported by Roberts (19) the art of grafting dates back more than 3,500 years. He referred to conversations with W. T. Chang in 1945, in which Chinese writings of 1560 B. C. implied the use of graftage by mentioning peach varieties. He also cited discussions of graftage by Aristotle (384-322 B. C.), Theophrastus (372-278 B. C.), Cato (234-149 B. C.) and Varro (116-27 B. C.).

The descriptions of cutting-grafts by Baltet (4) in 1882 and by Bailey (2) in 1891 are evidence that this kind of propagation was practiced before the turn of the century.

Cutting-grafts were used in the propagation of Junipers by Keen (15) and Buckley (7), in propagating Vibernum opulus by Teuscher (22) and in propagation of oranges by Helma (11). According to Swingle et al., (21) cutting-grafts have been used in Spain in the propagation of orange trees and according to Bioletti and Dal Piaz (5) this type of propagation was used for grapes in California. Baltet (4) mentioned the use of cutting-grafts to propagate orange trees, Camelia sp., Aucuba japonica and Euonymus japonicus.

Teuscher (22) in producing dwarf plants of the Snowball Viburnum, Viburnum opulus roseum, grafted scions of this plant onto unrooted cuttings of a smaller growing plant Viburnum opulus nanum, then rooted the cuttings. Rooting in a one to one mixture of peat and perlite, started in fourteen days and at the end of five weeks ninety percent of the cutting-grafts were successful. He observed that if rooting of the cutting was slow the graft union was poor. This procedure was also tried with lilac, Syringa sp., scions grafted onto cuttings of privet, Ligustrum sp., but the percent success was poor.

Helma (11) developed a method of using cutting grafts to propagate known varieties of citrus scions on known varieties of citrus rootstocks. This method was more rapid than the usual method of rooting cuttings of the desired rootstock then budding them to the preferred scion. In this process he tongue-grafted a leafy twig of the scion variety to a leafy cutting of the desired rootstock variety and tied the union with raffia. These cutting-grafts were then rooted like regular citrus cuttings. These grafts united in two weeks, as a rule, but rooting was governed by the variety used as the cutting. The plants produced by this method were comparable to budded plants.

Another method of employing cutting-grafts in citrus propagation, according to Swingle et al., (21), was studied in Valencia, Spain, by Dr. L. Trabut, Government Botanist of Algeria. In this procedure, a scion of citron, which is easily rooted, was grafted to a twig of the desired orange, and wrapped with waxed paper. When the graft had united both twig and scion were removed and planted. The citron soon produced roots. After one year the plants were transplanted and the citron and its roots removed, leaving

the orange on its own roots.

Standard Method of Grafting Junipers

Hill (12) and Chadwick (8) both stated that the reasons for propagating some Junipers by grafting are to reproduce those varieties that do not come true from seed and do not root well as cuttings. Hill (12) added that graftage is sometimes used to propagate those Junipers which root slowly in order to insure vigorous growth.

According to Snyder (20) the Redcedar is probably the most difficult of the Junipers to root from cuttings. This statement was supported by the work of Bogdany (6) who had only 33 percent success in rooting the Keteleer Juniper, Juniperus virginiana cl. 'Keteleer' in Connecticut. He took cuttings with a heel of two year wood in January and, after treating them with Hormodin No. 3, stuck them in coarse sand. The cuttings were left in the sand for three months. Using this same procedure he was able to root the Canaert Juniper, Juniperus virginiana cl. 'Canaert' with 75 percent success.

Hill (12) reported that the veneer graft was commonly used in grafting Junipers. Baltet (4) also mentioned the use of this type of graft. Keen (15) used the side graft to produce cutting-grafts of Juniper and Buckley (7) used both the side graft and veneer graft in his experiments with cutting-grafts.

Baltet (4) wrote that Juniper grafts could be held in a covered frame for six to eight weeks until the graft united. Wells (23) reported that Juniper grafts could be held on an open bench until they healed, if the potted root stocks were buried in the medium deep enough to cover the graft. He indicated that the humidity of the propagation room must be maintained

at a high level with this method. Hill (12) suggested not less than 85 percent relative humidity for this method. This open bench method was used by Keen (15) in rooting and healing cutting-grafts. He maintained the humidity with compressed air atomizing nozzles.

In a variation of the covered frame method, Kyle (16) reported grafting Junipers without potting the rootstocks. With this method he wrapped the roots of the rootstocks in paper and placed them in the grafting case as soon as the grafting was completed. This enabled him to put a larger number of Junipers in the grafting case by eliminating the bulk of the pots. In the production of Juniper cutting-grafts Buckley (7) stuck the completed cutting graft in a mixture of sand and peat and covered the bench with polyethylene.

Hill (12) suggested that temperatures of at least 75° F. were necessary for proper union of the graft. This agreed with work by Wells (23) who was able to produce only 65 percent successful grafts with temperatures of 60° F. but suffered only a 10 percent loss with temperatures of from 75° F. to 78° F.

Rootstocks Commonly Used for Grafting Junipers

Hill (12) reported the use, in commercial production of grafted Junipers, of Redcedar and Chinese Juniper, Juniperus chinensis, seedlings. He preferred to select the rootstocks, according to stem diameter, from seedlings at least two years old. According to Hill (12) these two species were considered to be the best rootstocks with the Redcedar being preferred. He stated that the main disadvantage in this case was the difficulty of growing the Redcedar consistently from seed in the nursery.

The Oriental Arborvitae, Thuja orientalis, was mentioned as a rootstock

for Juniper grafting by Mahlstede and Haber (18), Chandler (9), Chadwick (8) and Esper (10). Chandler (9) and Chadwick (8) considered this rootstock to be inferior to both Redcedar and Chinese Juniper, but Esper (10) stated that it was preferred by some nurserymen.

Buckley (7) suggested that Juniperus horizontalis cl. 'Andorra', the Andorra Juniper, might be an excellent rootstock for Redcedar clones, but Chandler (9) found that this rootstock caused declining vigor of the plant after the third year. He rated the Andorra Juniper as inferior to Chinese Juniper and Redcedar but superior to the Irish Juniper, Juniperus communis hiberica, Spiny Greek Juniper, Juniperus excelsa cl. 'Spiny' and the Oriental Arborvitae. Hill (12) considered the main disadvantage of the Andorra Juniper as a rootstock to be the lack of vigor of the grafted plant, but Chadwick (8) suggested, after observing that Redcedar clones on Andorra Juniper rootstocks were more compact than on other rootstocks, that this rootstock might be used to dwarf large varieties such as the Keteleer Juniper.

The Irish Juniper and the Greek Juniper were rated low as a rootstock for Redcedar clones by both Chandler (9) and Chadwick (8). Chandler (9) also considered Juniperus scopulorum to be undesirable as a rootstock because of the poor root system produced.

Other rootstocks used, at least in experimental work, include the Hetz Juniper, Juniperus virginiana cl. 'Hetz', by Keen (15) and the Koster Juniper, Juniperus virginiana cl. 'Koster', by Buckley (7). In both cases these rootstocks were used in producing cutting-grafts.

Stionic Effects

Esper (10) studying the effect of the rootstock on the production of scion and graft roots defined graft roots as those arising from the union of stock and scion, probably from adventitious tissue formed during the healing of the graft. He defined scion roots as those which were produced by the scion above the graft union. He found that different rootstocks did influence the number of scion and graft roots produced by the plants if the planting was done so that the graft union and part of the scion were below soil level.

Observations after the grafted Junipers had been in the transplant bed for one year revealed that more stock and scion roots were produced on plants grafted to rootstocks of Chinese Juniper and Spiny Greek Juniper than on those grafted to Redcedar rootstocks. Those scions grafted to Oriental Arborvitae produced the least roots of both the scion root and graft root type. The scion varieties used by Esper (10) were three clones of Redcedar, 'Canaert', 'Koster', and 'Glauca' and one variety of Chinese Juniper. In the case of the plants on Chinese Juniper rootstocks, the rootstock roots were well developed in addition to many scion and graft roots, but on those plants grafted to Redcedar rootstocks the scion and graft roots had almost displaced the rootstock roots.

Chadwick (8) found that both the kind of rootstock and the variety of the scion influenced the production of scion and graft roots. In his work no scion roots were produced when the Canaert Juniper, the Burk Juniper, Juniperus virginiana cl. 'Burk', the Hill's Dundee Juniper, Juniperus virginiana cl. 'Hill's Dundee' or the Keteleer Juniper were grafted on rootstocks of Irish Juniper, Spiny Greek Juniper, Redcedar, Oriental Arborvitae,

Chinese Juniper and the Andorra Juniper. Only on those plants having the Blue Columnar Juniper, Juniperus chinensis cl. 'Blue Columnar', as the scion were any scion roots produced and then only when either Chinese Juniper or Irish Juniper was used as the rootstock.

In addition to having no scion roots all those plants with the Hill's Dundee Juniper as the scion failed to produce roots from the graft. The Burk, Canaert, Keteleer and Blue Columnar Junipers all produced graft roots when they were on Irish Juniper rootstocks. Only the Canaert, Burk and Blue Columnar Junipers produced graft roots when grafted to the Andorra Juniper as a rootstock. With Redcedar as the rootstock only those plants with the Canaert Juniper and Blue Columnar Juniper grew graft roots. In addition the Blue Columnar Juniper grafted to the Spiny Greek Juniper grew a few graft roots.

Chadwick (8) also found that the scion variety influenced the quality of the roots of the rootstock. Plants with the Burk Juniper as the scion produced the heaviest, coarsest rootstock roots followed by Blue Columnar Juniper, Keteleer Juniper, Canaert Juniper and Hill's Dundee Juniper. Twice as many heavy, coarse roots were recorded on those plants with the Burk Juniper as scion as on those with the Hill's Dundee Juniper as scion.

Chandler (9) and Hill (12) both indicated that the rootstock may influence the growth of the scion by observing that the Andorra Juniper as a rootstock tended to dwarf the scion variety.

Chadwick (8) reported that after three years in the field the average height of the plants produced was greatest with Redcedar as the rootstock. Those plants on rootstocks of Irish Juniper were second largest followed by those on Chinese Juniper, Spiny Greek Juniper, Andorra Juniper and Oriental

Arborvitae in the order of decreasing average height. This order of greatest height was not consistent among the different scions. Except for the Keteleer Juniper, which was the tallest with the Irish Juniper as the rootstock, all scions tested were tallest on Redcedar rootstocks. Oriental Arborvitae as the rootstock produced plants which were in only one case as tall as those on the other rootstocks and as a rule were shorter.

In regard to quality of top growth Chandler (9) observed that plants with the Andorra Juniper as the rootstock were more compact than with the more common rootstocks. Chadwick (8) reported the same observation when the Canaert Juniper and the Keteleer Juniper were used as scions. On this rootstock Chadwick (8) also found that the Burk Juniper did not grow as erect as with other rootstocks and the Blue Columnar Juniper was not as uniform as it was on rootstocks of Redcedar, Chinese Juniper or Oriental Arborvitae. This lack of erectness of the Burk Juniper was also evident when the Chinese Juniper was the rootstock.

Chadwick (8), in making further observations on the effect of the rootstock on the quality of the top growth, reported that the Burk Juniper was compact on Irish Juniper roots, fairly compact on Redcedar and Chinese Juniper but, that quality of top growth was poor with the Andorra Juniper as the rootstock. Canaert Juniper grew fairly erect on all rootstocks. Top growth was most compact when Oriental Arborvitae was the rootstock and satisfactory with rootstocks of Redcedar. Irish Juniper as the rootstock produced loose and open growth with this scion variety. Redcedar, Chinese Juniper and Oriental Arborvitae rootstocks all produced compact, uniform growth of the Blue Columnar Juniper, but quality of top growth was less satisfactory with rootstocks of Irish, Spiny Greek and Andorra Junipers.

In addition to proposing that the Andorra Juniper might be a good dwarfing rootstock for the Keteleer Juniper, due to the short and compact top growth of this combination, Chadwick (8) observed that Oriental Arborvitae as the rootstock also produced very compact top growth. Those plants with Redcedar as the rootstock were also compact in their growth habit, but those with the Irish and Spiny Greek Juniper as the rootstock produced a thin unsatisfactory top growth.

Chadwick (8), in summarizing his work, stated that survival of grafted Junipers in the field was best with Redcedar as the rootstock and poorest with rootstocks of Irish Juniper and Oriental Arborvitae. He also observed that the production of heavy, coarse graft and rootstock roots favored the growth of the scion variety.

Cutting-Grafts of Junipers

Keen (15), in 1951, reported that he had been successful in producing grafted Junipers from cutting-grafts of the Burk Juniper grafted onto cuttings of the Hetz Juniper and the Koster Juniper grafted onto cuttings of the Andorra Juniper. In January, he bark grafted the scions to large unrooted cuttings of the Hetz and Andorra Junipers, placing the bottom of the graft at least one inch above the base of the cuttings. After the grafts had been tied with rubber budding strips, the base of the cuttings were dipped in Hormodin No. 1. The cutting grafts were then stuck in a medium of coarse vermiculite to a depth covering the top of the graft.

Temperatures were controlled at 68° F. and the humidity was maintained by Binks No. 164 nozzles, which combine compressed air and water to form a fine mist, as described by Laurie and Kiplinger (17).

Three months later the rooted cutting-grafts were potted and at that time 63 percent of the Burk Juniper Hetz/Juniper grafts and 64 percent of the Koster Juniper/Andorra Juniper grafts were successful.

Additional work with cutting-grafts of Junipers was done by Buckley (7) in 1955 and 1956. In 1955 he grafted the Hill's Dundee Juniper and the Canaert Juniper onto cuttings of the Creeping Juniper, Juniperus horizontalis, and the Savin Juniper, Juniperus sabina. These cutting-grafts were stuck in a mixture of peat and sand under polyethylene and syringed twice daily. After two months, a large majority of these cutting-grafts were successful.

For the 1956 experiment, Hill's Dundee Juniper and the Silver Juniper, Juniperus virginiana cl. 'Glauca' were used as scions and the Koster Juniper, Andorra Juniper, Savin Juniper and Vonehron Juniper, Juniperus sabina cl. 'Vonehron', were used as cuttings. These scions and cuttings were united with side and veneer grafts and tied with strips of polyethylene. After the base of the cutting had been dipped in Stim Root 10, which is similar to Hormodin No. 3, the cutting-grafts were stuck in vermiculite under mist. The graft union was left just above the surface of the vermiculite.

With temperatures of 65° F. at night and 75° F. in the daytime there was some variation in the number of successful cutting-grafts after about five months in the bench. Of the 25 Hill's Dundee/Savin Juniper combinations 17 rooted, but only 15 of the grafts united. With this scion on Koster Juniper 17 of 22 cutting-grafts rooted but only 16 grafts united and with the Vonehron Juniper as the rootstock 16 of 20 were successful in rooting and uniting of the graft. Of the Hill's Dundee/Andorra Juniper combination 20 of 25 were successful, of the Silver Juniper/Koster Juniper combination 12 of 25 rooted, but only 10 of these grafts united and of the final

combination of Silver Juniper/Vonehron Juniper only 18 of 25 resulted in rooted cutting-grafts.

Mahlstede and Haber (18) in their discussion of cutting-grafting stated that the success of cutting-grafts is more dependent on the culture of the plants after grafting than the type of graft used. They also observed that success of cutting-grafts was dependent on three factors, the formation of a graft union, rooting of the cutting, and growth of the cutting.

Keen (15) and Buckley (7) in discussing their experiments expressed opinions concerning the advantages and commercial possibilities of cutting-grafts of Junipers.

Buckley (7) stated that cutting-grafting was a more simple operation than grafting on a potted rootstock. He also presented the possibility that machine tieing of cutting-grafts might be used.

Keen (15) reported that cutting-grafts in addition to shortening the time and thus reducing the cost of production of grafted Junipers might make it possible to produce two grafted plants from one potted rootstock. This would be done by grafting the potted rootstock early in the season, then making a cutting-graft of the rootstock top when it was removed.

Helma (11) stated in his report on citrus cutting-grafts that this procedure might be used to test congeniality between untried varieties.

METHODS AND MATERIALS

Plant Materials Used

The Redcedar seedlings which were used as potted rootstocks for one-third of the grafts were gathered from the hills north of Manhattan, Kansas, on December 12, 1957. The seedlings were potted in three inch clay rose pots

and held in the greenhouse until ready to graft. A few seedlings which had been gathered in the fall of 1956 and were established in pots were also used. The best seedlings from the six hundred gathered were selected for grafting, but even these were of inferior quality. Many of them were larger than desired and some were not straight stemmed enough for the easiest grafting.

Phomopsis blight, Phomopsis juniperovora, was detected on some of the collected seedlings while they were being held in the greenhouse. As a control measure the entire propagation house and all the plants in it were sprayed with a mixture of 9.1 grams of Captan 50 W (N trichloromethyl thio tetrahydrophthalimide) in one gallon of water. All infected branches which showed typical dying back of the tips were clipped and removed from the greenhouse.

Plant material, for all the scions and the cuttings which served as rootstocks, was collected from a local nursery on January 29, 1958. These scions and cuttings were placed in plastic bags with a small amount of water and stored in common storage at about three to four degrees centigrade until they were needed for grafting. Both scions and cuttings were made from vigorous tip cuttings of the current seasons growth. All cuttings were taken in longer lengths than needed so that the base of the scion or cutting would be made by a fresh cut when the cutting was reduced to the proper size at grafting time.

Cuttings of the Hetz Juniper were taken from plants about eight years old that had been grown from cuttings. Cuttings of the Andorra Juniper were taken from large seven year old plants which were also grown from cuttings.

Wood for the scions was taken from the leaders and vigorous side branches of the Nevin's Blue Juniper, Juniperus virginiana cl. 'Nevin's Blue' and the Canaert Juniper which were grown from grafts on Redcedar seedlings and were

eight and two years old from the graft respectively.

Grafting Methods

Joining of the scion and potted rootstock or cutting was accomplished by a side graft or, in the case of a few of the potted rootstocks, a veneer graft. In either case the graft was made as near to the soil level as possible on the potted rootstocks and at least 2.5 centimeters above the base on the cuttings. In all the grafts, care was taken that the flap of bark which was cut loose on the rootstock or cutting was thin and pliable so that it could be molded to the contour of the outside cut surface of the scion. Pressure was applied to hold the scion and rootstock or cutting together by the rubber budding strip with which the graft was tied. (Plate I).

When the scion had been grafted to the cutting and tied, the base of the cutting was given a light wound on the side opposite the graft and dipped in Hormodin No. II (.3 percent indolebutyric acid in talc) to a depth of one-half inch. These finished cutting grafts were then stuck and the potted rootstocks were plunged in a bench filled with a coarse insulation grade of vermiculite called Zonolite. The pots were tipped at a 45 degree angle so that they would not become waterlogged when the vermiculite was watered. The pots and the lower part of the stems of the potted plants and the cuttings were covered to a depth of two or three centimeters above the top of the graft with the vermiculite.

Conditions for Healing

The propagation room in which the grafts were held was a six by thirty-six foot north lean-to in which the humidity was maintained by Binks No. 164

EXPLANATION OF PLATE I

Left to right; cutting of Hetz Juniper, cutting of Andorra Juniper, scion of Nevin's Blue Juniper, scion of Canaert Juniper, rubber budding strips, completed cutting-grafts of Canaert Juniper/Hetz Juniper and Nevin's Juniper/Andorra Juniper.

PLATE I

compressed air atomizing nozzles which mix compressed air and water to form a fine mist. These nozzles maintained the relative humidity at 65 percent and above except during the warmest part of the day when it sometimes fell to 45 percent and during warm days in early May when temperatures of 32° to 38° C. and relative humidities of 30 percent were recorded by the hygrothermograph.

Heat was supplied to the propagation room by steam pipes under the bench to apply bottom heat and one larger pipe above the bench to provide auxiliary heat during cold weather. The temperature was thermostatically controlled at 22° C. but showed considerable variation from that desired thermostat setting. A low temperature of 8° C. was recorded on February 13, 14, and 16. A continuous record of temperatures was made with a hygrothermograph as shown by the maximum and minimum daily temperatures in Table 1.

The plants were watered as needed by hand spraying with tap water from a hose. The frequency of watering ranged from every third day in cold, cloudy weather to as often as twice daily on warm sunny days in April and May.

Time of Grafting

The first grafting was done on February 1, 3, and 7, 1958, when 40 Canaert Juniper and 60 Nevin's Blue Juniper were grafted onto each of the two kinds of cuttings and the potted seedling rootstocks. The date of grafting was determined by the root growth of the seedling rootstocks. They were not grafted until at least one centimeter of new root growth could be seen when the plant was knocked out of the pot.

The second grafting was done as soon as more of the seedling rootstocks

Table 1. Maximum and minimum temperatures of the propagation house in degrees centigrade.

Date	Maximum temperature	Minimum temperature
February 13, 1958	14	8
" 14	19	8
" 15	19	10
" 16	13	8
" 17	19	9
" 18	25	15
" 19	23	13
" 20	26	18
" 21	27	20
" 22	27	13
" 23	23	11
" 24	23	9
" 25	24	17
" 26	21	14
" 27	19	17
" 28	20	16
March 1, 1958	26	16
" 2	20	17
" 3	*	*
" 4	24	14
" 5	19	14
" 6	20	18
" 7	21	18
" 8	20	16
" 9	23	17
" 10	21	18
" 11	23	18
" 12	21	17
" 13	23	16
" 14	24	16
" 15	23	16
" 16	24	17
" 17	24	19
" 18	24	18
" 19	24	18
" 20	21	17
" 21	24	17
" 22	23	20
" 23	23	19
" 24	24	18
" 25	25	19
" 26	24	19
" 27	25	20
" 28	27	17
" 29	29	14
" 30	25	17
" 31	25	17

Table 1 (cont.)

Date	Maximum temperature	Minimum temperature
April 1, 1958	26	18
" 2	25	19
" 3	24	19
" 4	26	19
" 5	23	17
" 6	19	13
" 7	23	20
" 8	27	16
" 9	20	17
" 10	23	17
" 11	*	*
" 12	25	20
" 13	31	21
" 14	*	*
" 15	28	19
" 16	30	18
" 17	*	*
" 18	27	19
" 19	31	18
" 20	29	18
" 21	25	18
" 22	26	17
" 23	32	18
" 24	27	17
" 25	30	18
" 26	28	20
" 27	28	19
" 28	30	19
" 29	30	16
" 30	34	18
May 1, 1958	34	17
" 2	26	18
" 3	21	17
" 4	22	18
" 5	34	18
" 6	37	20
" 7	33	19
" 8	26	16
" 9	32	13
" 10	36	16
" 11	40	17
" 12	37	19
" 13	29	19
" 14	29	18
" 15	27	17
" 16	27	16
" 17	28	17

Table 1. (concl.)

Date	Maximum temperature	Minimum temperature
May 18, 1958	26	17
" 19	28	14
" 20	31	16
" 21	29	16
" 22	29	18
" 23	21	15
" 24	28	16
" 25	30	16
" 26	32	18
" 27	31	17
" 28	29	16
" 29	30	18

*Temperature not recorded

were ready to graft. On February 17, grafting was continued by grafting one-half as many of each scion, rootstock or cutting combination. This added 20 Canaert Juniper and 30 Nevin's Blue Juniper on each of the two kinds of cuttings and the potted rootstocks.

Grafting was completed on March 3, 1958, with the grafting of 40 Canaert Juniper and 60 Nevin's Blue Juniper as done in the first grafting. This made a total of 100 Canaert Juniper and 150 Nevin's Blue Juniper grafted on each of Hetz Juniper cuttings, Andorra Juniper cuttings and potted Redcedar seedlings.

Rootstock Top Removal

The top of the Redcedar seedling rootstocks were removed with two cuts. The first cut was made to remove one-half of the rootstock top about four weeks after grafting. Two weeks later the remainder was removed with a second cut. When the last part of the rootstock was removed the potted grafted plants were removed from the vermiculite and staged on an open bench

in the same propagation house.

Potting of Cutting-grafts

As soon as more than one-half of the cutting-grafts from each time of grafting appeared to have produced roots, Plate II, they were lifted and those with roots potted in three inch rose pots and staged on an open bench. The soil used was a mixture of four parts soil to one part peat. Those cutting-grafts which had not rooted were returned to the vermiculite. In potting the cutting-grafts one-half of the graft was left above the soil level to facilitate removal of the rubber budding strip at a later date. (Plate III).

The cutting-grafts were allowed to remain in the pots for four weeks before the cutting top was removed in one operation.

On May 13, potting of the cutting-grafts which had rooted was completed and on May 20 the atomizing nozzles were turned off to reduce the humidity and harden the plants. Those cutting-grafts which had not rooted were returned to the vermiculite and left until August 16, 1958.

A final count of the grafts which were successful was made on May 28, and the removal of cutting-graft cutting tops was completed. As all of the cutting-grafts which produced roots were potted, failure of the scion on these potted cutting-grafts to remain alive was attributed to an unsuccessful graft union.

Field Planting

The successful grafts were randomly plotted on a map of the field where they were to be planted. Three, of all but one of each of the 18 different scion, rootstock, time of grafting combinations were included in each of five

EXPLANATION OF PLATE II

Left to right; three rooted cutting-grafts with Andorra Juniper as the rootstock, three rooted cutting-grafts with Hetz Juniper as the rootstock.

PLATE II

EXPLANATION OF PLATE III

Left to right; rooted cutting-graft, potted cutting-graft, potted cutting-graft with the rootstock top removed, rootstock top that was removed.

PLATE III

replicated blocks. There were only 14 surviving plants of one combination. The plants in these five blocks were used to determine increase in height of each combination. The remainder of the plants were planted around the blocks as guard rows and in a nearby plot and were included in the field survival counts.

The grafted Junipers were planted May 30, 1958, one meter apart in rows which were one meter apart and checked so that they could be cultivated in two directions. The soil where they were planted was a silty loam loess soil which had been spring plowed and fertilized with 84 pounds of nitrogen and 174 pounds of phosphorus per acre. The soil was worked to a firm seedbed and the Junipers planted with the top of the graft two to three centimeters below the surface of the soil. The plants were watered with about two liters of water around each plant.

Field Culture of Junipers

After the Junipers were planted they were cultivated in two directions to level the field and those plants in the five replicated blocks were measured to the nearest centimeter of height.

The field in which the Junipers were planted was clean cultivated from May 30, 1958, until the height of the Junipers was measured at the end of the growing season, on November 16, 1958, to determine the increase in height during the summer. Field survival counts were made at this time.

Moisture content of the soil was satisfactory at planting time and rainfall was above average during the summer months, totaling over 85 centimeters between June 1 and October 30, 1958.

Erosion damage was caused by a heavy rain on June 9, 1958. The damage

was heaviest in block No. I, but none of the plants were washed out. Damage from other heavy rains later in the summer was avoided by the construction of a terrace above the field to divert drainage water from higher ground.

After the final measurements were taken, a fence of one inch mesh chicken wire two feet high was built around the five replicated blocks to prevent damage to the Junipers by rabbits. This precaution was taken so that growth studies could be continued during the summer of 1959.

Study on Time of Grafting

A supplementary study was conducted during the winter of 1958 and 1959 to determine the effect of the time of grafting on the success of cutting-grafts. On October 15, November 2, November 20, December 8, and December 29, 1958, and January 17, 1959, ten scions each of the Nevin's Blue Juniper, the Canaert Juniper, the Keteleer Juniper, and the Kenyon Juniper, Juniperus scopulorum cl. 'Kenyon', were grafted to cuttings of the Hetz Juniper as previously described and stuck in the same propagation bench that was used the year before. The cutting-grafts were potted as they produced roots and the number of successful grafts recorded.

RESULTS

Success of Grafting

The number of each scion, rootstock, time of grafting combination which resulted in successful grafted Junipers and the percent success calculated from these numbers are shown in Table 2. All plants not accounted for failed to root in the cutting bench.

Table 2. Success of grafts as taken from the propagation house.

Combination	Number Grafted	Number Planted May 30	% Success	Number Rooted After May 30	Number Grafts Not United	Total % Success
T_1, S_c, R_v	40	31	77.5	0	9	77.5
T_1, S_c, R_h	40	35	87.5	3	2	95.0
T_1, S_c, R_a	40	31	77.5	1	4	80.0
T_2, S_c, R_v	20	17	85.0	0	3	85.0
T_2, S_c, R_h	20	14	70.0	0	0	70.0
T_2, S_c, R_a	20	17	85.0	0	1	85.0
T_3, S_c, R_v	40	26	65.0	0	14	65.0
T_3, S_c, R_h	40	26	65.0	6	1	80.0
T_3, S_c, R_a	40	38	95.0	2	0	100.0
T_1, S_n, R_v	60	36	60.0	0	24	60.0
T_1, S_n, R_h	60	52	86.6	1	4	88.3
T_1, S_n, R_a	60	47	78.3	1	3	80.0
T_2, S_n, R_v	30	27	90.0	0	3	90.0
T_2, S_n, R_a	30	26	86.6	1	0	90.0
T_3, S_n, R_v	60	47	78.3	0	13	78.3
T_3, S_n, R_h	60	33	55.0	16	1	81.6
T_3, S_n, R_a	60	44	73.3	7	1	85.0

T_1 - First time of grafting (February 2-7)
T_2 - Second time of grafting (February 17)
T_3 - Third time of grafting (March 3)
S_c - Canaert Juniper as the scion
S_n - Nevin's Blue Juniper as the scion
R_v - Potted Redcedar as the rootstock
R_h - Cutting of Hetz Juniper as the rootstock
R_a - Cutting of Andorra Juniper as the rootstock

Field Survival

Field survival of each of the natural groups of rootstock, scion or time of grafting is shown in Table 3. The percent survival of these groups is also shown.

Table 3. Field survival of grafted Junipers.

Natural Group	Number Planted	Number Survived	Percent Survival
Plants with Canaert as the scion	236	206	87.3
Plants with Nevin's Blue as the scion	340	301	88.5
Plants with Redcedar as rootstock	184	176	95.7
Plants with Hetz Juniper as rootstock	189	159	84.1
Plants with Andorra Juniper as rootstock	203	182	89.7
Plants from first time of grafting	232	208	89.7
Plants from second time of grafting	130	112	86.2
Plants from third time of grafting	214	199	93.0

Increase in Height

Growth of the Junipers in the field was recorded as increase in height and arithmetic means of these measurements for each natural group of rootstock, scion or time of grafting are shown in Table 4.

Table 4. Mean increase in height of Junipers in the field, in centimeters.

Natural Group	Block I	Block II	Block III	Block IV	Block V	All Blocks
Plants with Canaert as the scion	10.83	19.05	14.73	17.42	14.46	15.21
Plants with Nevin's Blue as the scion	21.87	20.85	22.04	20.96	17.90	20.66
Plants with Redcedar as rootstock	19.06	23.41	24.76	23.35	23.19	22.71
Plants with Hetz Juniper as rootstock	14.00	19.07	16.06	19.35	14.29	16.62
Plants with Andorra Juniper as rootstock	13.71	15.11	14.22	14.81	10.65	13.71
Plants from first time of grafting	13.13	19.50	22.50	19.47	14.00	17.86
Plants from second time of grafting	17.20	20.38	17.70	18.94	20.33	18.90
Plants from third time of grafting	17.31	17.59	14.25	19.38	13.94	16.50

In calculating the means in Table 4 only those plants which survived until the end of the growing season were included. All measurements were made from ground level to the end of the highest twig of each plant.

STATISTICAL ANALYSIS

Analysis of Success of Grafting

In the analysis of the data presented in Table 2 a chi-square test was applied to determine if there were significant differences in the number of successful Juniper grafts among the 18 different combinations of rootstock, scion and time of grafting as they were taken from the propagation house to the field. As shown in Table 5 there were real differences. Chi-square tests were then used to analyze the differences in success among the plants on each of the three rootstocks, between plants with each of the two scions and among plants from each of the three times of grafting. These results are also shown in Table 5, as are the results of the chi-square analysis of differences between success of the three possible combinations of time of grafting. This last analysis was made necessary by the large chi-square obtained from the analysis of success from the three times of grafting.

Table 5. Chi-square analysis of successful Juniper grafts at planting time.

Comparison made	Chi-square	Degrees of freedom	Significance
18 combinations of time of grafting, rootstock, and scion	56.598	17	.005
3 rootstocks	4.487	2	ns[1]
2 scions	.7758	1	ns
3 times of grafting	12.1536	2	.005
Time I with Time II	4.360	1	.05
Time I with Time III	2.797	1	ns
Time II with Time III	11.065	1	.005

[1] - Not significant at the .05 level.

Analysis of Field Survival

The chi-square test was again used to analyze the data from survival of the plants in the field during the growing season. The survival of 18 different combinations of rootstock, scion and time of grafting were compared. This comparison yielded a significant chi-square as shown in Table 6. Comparisons were then made among the three rootstock groups, between the two scion groups and among the three groups from the different times of grafting. As can be seen in the table only the comparison of rootstocks gave a significant chi-square. This led to the comparison of all possible combinations of the three rootstock groups. The chi-squares obtained are shown in Table 6.

Table 6. Chi-square analysis of survival of plants in the field.

Comparison made	Chi-square	Degrees of freedom	Significance
18 combinations of time of grafting, rootstock, and scion	41.098	17	.005
3 rootstocks	13.469	2	.005
2 scions	.198	1	ns[1]
3 times of grafting	4.325	2	ns
Redcedar rootstocks and Hetz Juniper rootstocks	3.529	1	.005
Redcedar rootstocks and Andorra rootstocks	5.031	1	.025
Hetz Juniper and Andorra rootstocks	2.7082	1	ns

[1] - Not significant at the .05 level.

Analysis of Increase in Height

In the statistical analysis of the data from the measurements of increase in height of the plants in the five replicated blocks, the analysis of variance method was used. First the variance of the three plants of the same rootstock, scion, time of grafting combination in each block was calculated. These values were plotted on a graph against the mean of the three measurements to determine if there was any trend in this relationship. There appeared to be no definite trend for all the plotted points or for those of any natural group such as those for plants on one rootstock or with one kind of scion.

Analysis of variance of the data was made as outlined in Table 7.

It could be seen from this analysis that the variance was significant at the .05 level only among the three groups on each of the three different rootstocks and at the .10 level between plants with different scions. By observing the means of the increase in height of each of the two groups with different scions it was concluded that on the average plants with scions of the Nevin's Blue Juniper increased more in height than those with scions of the Canaert Juniper.

From the data on the plants from each of the three rootstock groups a value of 4.26 centimeters was calculated as the least significant difference between the means of any two of these groups. With means as shown in Table 4 of 22.71 centimeters for those plants with Redcedar as the rootstock, 16.62 centimeters for those plants with the Hetz Juniper as a rootstock, and 13.71 centimeters for those plants with the Andorra Juniper as a rootstock, there was a significant difference between the first group and either of the last two groups, but not between the last two groups.

Table 7. Analysis of variance of increase in height data.

Sources of variation	Degrees of freedom	Sum of squares	Mean squares and significance
Combinations	17	7,062.99	424.47
Rootstocks 2		(4,062.99)	(2,031.50)**
Scions 1		(1,909.35)	(1,909.35)*
Times 2		(181.09)	(90.55)ns[1]
Rs[2] x Sc[3] 2		(348.85)	(174.43)ns
Rs x Time 4		(550.41)	(137.60)ns
Sc x Time 2		(115.55)	(57.78)ns
ScxRsxTime 4		(47.75)	(11.94)ns
Blocks	4	904.39	226.09ns
Blocks x combinations	68	13,892.66	204.30ns
Plants same combination and block	179	8,864.95	49.52ns
Totals	268	30,877.99	-

1 - Not significant
2 - Rootstocks
3 - Scions
* - Significant at .1 level
** - Significant at .05 level

Analysis of the Affect of Injured Plants

Further analysis of the data collected on increase in height was made necessary because of mechanical injury to some of the plants during cultivation. As the plants injured were predominately from the group with the Canaert Juniper as the scion, a t-test was applied to the measurement data to determine if there was a significant difference between the increase in height of the two groups of plants with different scion varieties when only those plants which were uninjured were included in the test. This test yielded a t value of 3.88 with 44 degrees of freedom which was significant beyond the .01 level, indicating a significant difference.

Statistical analysis was completed with a chi-square test to determine

if there were real differences among the number of plants injured from the three rootstock groups. Comparing all three groups, gave a chi-square of 9.879 with 2 degrees of freedom which was significant at the .005 level. As this indicated that there were significant differences among these three groups, all possible combinations of the three were subjected to the same test. Comparing the number of injured and uninjured plants from the group which had Redcedar seedlings as rootstocks with those from the groups which had the Hetz Juniper and those which had the Andorra Juniper cuttings as rootstocks yielded chi-squares of 7.177 and 9.370 respectively. The first of these values was significant at the .01 level and the second at the .005 level. In comparing the number of injured plants from the two groups of plants with cuttings as rootstocks a chi-square of only .144 was obtained, which was not significant at the .05 level.

CONCLUSIONS BASED ON STATISTICAL ANALYSIS OF THE DATA

Conclusions About Success of Grafting

In this experiment there was a difference in the number of successful grafts and cutting-grafts due to time of grafting. Several factors may have contributed to this difference. Examination of the percent success data in Table 2 indicated that low percentages for the first time of grafting were from those plants with Redcedar rootstocks. Low temperatures on February 13, 14, and 16 might have been a factor in the failure of some of these grafts to heal properly. Low percentages in the group of plants from the last time of grafting are from those plants with the Hetz Juniper as the rootstock, as well as some low figures from those groups on Redcedar roots. In the first case the cutting did not have sufficient time in the cutting

bench to produce roots, as proven by the fact that many of these cutting-grafts rooted later in the summer. Failure of the grafts on Redcedar cannot be attributed to low temperatures in this case, but might have been caused by the poor quality of the understocks used. All these factors tended to make the percent success in the first and last grafting lower and more nearly alike than either was like the percent success from the second time of grafting.

These observations tend to minimize the affect of time of grafting on the success of the process in this experiment, however, in later experiments, investigating the commercial possibilities of cutting-grafts, time of grafting was a factor in success of rooting. As shown in Table 8, 10 cutting-grafts of each of four different varieties of Juniper sp. grafted on Hetz Juniper cuttings were made on six different dates, at about 18 day intervals. The percent success from each combination of scion and time of grafting are shown in the table.

Table 8. Results of time of grafting study, showing percent success.[1]

Scion	Date grafted					
	Oct. 15	Nov. 2	Nov. 18	Dec. 18	Dec. 29	Jan. 17
	%	%	%	%	%	%
Canaert Juniper	0	30	80	70	90	80
Nevin's Blue Juniper	0	30	70	40	80	80
Kenyon Juniper	30	10	40	80	90	60
Keteleer Juniper	20	20	60	50	50	70
Total %	12.5	22.5	62.5	62.0	77.5	72.5

1 - This study conducted in the winter of 1958-59 with conditions as described under methods.

The scion or rootstock used had no significant effect on the success of the grafting process in this experiment.

Conclusions About Field Survival

Neither time of grafting nor the scion variety had a significant affect on the survival of the plants after they were transplanted to the field. The rootstock on which the plants were growing did have some influence on the field survival. Survival was better with plants which had been grafted onto the potted Redcedar rootstocks, than with either of the other two groups which were grafted onto cuttings. There was no real difference in percent survival between the plants on Hetz Juniper and those on Andorra Juniper roots. This might be explained by the fact that the Redcedar rootstocks had been established in the pots longer and had stronger root systems at the time of transplanting than the other two kinds of rootstocks.

Conclusions About Increase in Height

In this experiment the following conclusions were made from the analysis of the increase in height data. Redcedar as the rootstock produced more increase in height than did either Hetz Juniper or Andorra Juniper. There was no real difference in the amount of increase in height between the two groups of plants on rootstock of Hetz Juniper and Andorra Juniper. Plants with Nevin's Blue Juniper as the scion increased more in height than did those with Canaert Juniper as the scion. This was true when those plants which had been mechanically injured were excluded from the calculations and when they were included. More plants were injured from the groups with the two kinds of cuttings as rootstocks than from the plants with the seedling rootstocks. There was no real difference in the number of plants injured from the two cutting rootstock groups.

As studied in this experiment, the time of grafting had no affect on the

amount of increase in height produced by the plants.

Time of grafting, kind of scion, and kind of rootstock used did not interact in this experiment.

The mechanical injury was almost entirely confined to those plants with Canaert Juniper as the scion. This plant had a tendency to grow prostrate rather than upright, which accounted for more injury from the cultivating equipment. This prostrate habit was more pronounced in those plants with understocks of the spreading type plants, Hetz Juniper and Andorra Juniper.

DISCUSSION

The percent successful cutting-grafts in this experiment was greater than those obtained by either Keen (15) or Buckley (7) and was not significantly different from the percent success with standard methods of grafting onto potted rootstocks.

Field survival of cutting-grafts was less than that for grafts onto potted rootstocks, but in all cases averaged more than 84 percent.

Growth rate for only one season is probably a poor criterion for judging the effect of a rootstock on scion growth, but observations of this type agree with Chadwick (8), and Hill (12) who observed that the Andorra Juniper as a rootstock produced less scion growth than did Redcedar. More valid conclusions can be made concerning the effect of the Hetz Juniper and Andorra Juniper on rate of growth and their compatability with the different scions after one or two more seasons of growth.

The lack of erectness of the Canaert Juniper when grafted to cuttings of Hetz Juniper and Andorra Juniper as found in this experiment was not observed by Chadwick (8) who found that the Canaert Juniper grew upright on

all the rootstocks he tested, including the Andorra Juniper. Chadwick (8) did find, however, that the Burk Juniper tended to grow prostrate on rootstocks of the Chinese Juniper and the Andorra Juniper.

CONCLUSIONS REGARDING COMMERCIAL POSSIBILITIES OF CUTTING-GRAFTS

Attempts to apply the findings of this experiment in making predictions about the practicality of cutting-grafts on a commercial basis must necessarily be tempered by the limited duration of the experiment. It would be desirable to have data from several years of field growth in order to fully evaluate the effects of compatability and growth rates of the scion rootstock combinations used. However, with the data available, cutting-grafting appears to be a practical method of producing grafted Junipers, although less growth should be expected from cutting grafts than from grafts onto potted rootstocks, at least during the first season. Survival in the field is likely to be lower with the cutting-grafted plants and with cuttings of the Andorra Juniper as a rootstock, the plant may lack erectness.

This experiment indicated that timing is important in making cutting-grafts. The grafts must be made from cuttings taken late enough in the winter that they will root readily, but early enough to allow sufficient time for the cutting-grafts to become established in the pots before being transplanted into the field. This time would be between Christmas and the middle of March, most years, in the Manhattan area.

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THE USE OF CUTTING-GRAFTS FOR PRODUCING GRAFTED JUNIPERS

by

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This experiment was conducted to investigate some of the factors, including compatability, success of propagation, field survival, and rate of growth, which are related to the practicability of the commercial production of grafted Junipers from cutting-grafts.

Potted seedlings of Redcedar, Juniperus virginiana, which served as controls, cuttings of the Andorra Juniper, Juniperus horizontalis cl. 'Andorra', and cuttings of the Hetz Juniper, Juniperus virginiana cl. 'Hetz' were used as rootstocks for grafting scions of the Canaert Juniper, Juniperus virginiana cl. 'Canaert' and the Nevin's Blue Juniper, Juniperus virginiana cl. 'Nevin's Blue'. Grafting was done on these different dates, February 1, 3, 7, 17, and March 3, 1958. A total of 150 of each rootstock-scion combination was grafted.

The union of rootstock and scion was made with either the side or veneer graft and in the case of the cutting-grafts, the bottom of the graft was made 2.5 centimeters above the base of the large 20 to 25 centimeter long cutting. The cuttings were given a light wound and dipped in Hormodin No. 2.

The grafted potted plants and the completed cutting-grafts were plunged in a coarse (Zonolite) grade of vermiculite to a depth just covering the top of the graft. The humidity of the propagation house was maintained by the use of compressed air atomizing nozzles and the temperature was thermostatically controlled at 22° C.

The grafted Junipers were held in the propagation house until May 30, 1958, when they were randomly planted in the field and their height measured.

Survival counts and measurements for increase in height were made on November 16, 1958.

Statistical analysis of the data collected was made to determine

differences in success of grafting, field survival and increase in height as affected by time of grafting, scion used and rootstock used.

This analysis indicated that the time that the grafts were made had an affect on success of grafting, but not on field survival or increase in height of the plants in the field.

The scion used did not affect the success of the grafting operation, the success of rooting of the cutting-grafts, or the field survival of the Juniper grafts. Plants with the Nevin's Blue Juniper as the scion, increased more in height than did those with the Canaert Juniper as the scion. This was true regardless of whether plants injured by cultivation were included in the calculations or not.

The rootstock used had no affect on success of the grafting and rooting process, but, both field survival and increase in height were affected by this factor. Both survival and increase in height was significantly greater with those plants on Redcedar roots, but there was no real difference between the two groups of plants with cuttings as rootstocks in these respects.

There was no interaction of time of grafting, rootstock used and scion used, in this experiment.

These results indicate that cutting-grafts could be used to commercially produce grafted Junipers; however, further observations of this project to determine compatability and rate of growth over a period of several years are needed before final recommendations can be made.