ORNAMENTALS NORTHWEST ARCHIVES

March-April 1989
Vol.13, Issue 2
Pages 9-12

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PHYSIOLOGY AND CULTURE OF *PICEA PUNGENS* ' HOOPSI' /*PICEA ABIES* GRAFTS

Many cultivars of ornamental conifers are difficult to propagate. Cuttings may root poorly and graft success may be highly variable even in the hands of skilled, experienced propagators. Because of these problems, we conducted a detailed study of the physiology of graft formation *in Picea pungens* 'Hoopsi' scions grafted on *Picea abies* rootstocks with the purpose of identifying factors limiting graft success and screening practical treatments designed to improve production.

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The first point to emphasize is the skill and care applied to making and wrapping the graft. One of us (R.C.B.) an excellent grafter, and showed that careful alignment of the cambia of scion and stock is the first and perhaps most important factor in grafting conifers. These difficult-to-propagate species callus poorly, so close proximity of the cambial layers (the site of cell division) is a critical first step. The treatments described below will be largely wasted if the graft is inadequate to begin with.

Commonly, spruce is grafted in heated greenhouses in the winter. Rootstocks are forced into active growth; then, dormant scions are grafted onto them. The rationale for this practice is sensible: The actively dividing cambium of the stock should produce callus bridges to the scion more quickly, while the dormant scion should be more resistant to stress. We found that within two weeks after grafting, a callus bridge had formed and was an important source of water to the scion. However, in the first week after grafting, the average scion had dried to about -19 bars, which is near the critical water potential below which the scion dies. At about -20 bars, stomata regulation on the scion fails, and a precipitous loss of water results. Thus, the scions after grafting can become precariously dry in the greenhouse environment; moisture stress resulting from malfunctioning heaters, extremely sunny weather, etc. may result in loss of many scions, - even those otherwise well-grafted.

Besides water relations, we also studied the use and movement of stored carbon, such as sugars and lipids, in the scion during graft formation. We found that these factors did not limit graft success. Likewise, photosynthesis by the scion during graft formation did not appear to be a limiting factor. The amount of stored carbon in the scion appears to be ample to supply the needs

of the scion during graft formation. There is very little carbohydrate translocated by the scion to the graft during graft formation. This lack of carbohydrate translocation correlates with the low water potential and the low rates of cell division in the scion. Conversely, considerable carbon is translocated to the graft union by the rootstock, consistent with the higher rates of callus formation by this tissue.

Little carbohydrate is translocated by the scion to the graft during graft formation. But, considerable is translocated from the rootstock.

As a result of our studies of graft development, the following treatments were tested to either reduce water stress in the scions or to stimulate callus development at the graft union and thereby improve graft success.

1) Post graft Environment:

A simple alternative to production in heated greenhouses is to use dormant rootstocks and hold the grafted plants in a coldframe during graft formation. We tested this procedure and found that although development was slower, water potential of the scions remained higher after grafting. Thus, the scions experienced less stress during graft formation.

Success of lathhouse grown grafts was always equal to or better than the greenhouse-grown grafts.

In a controlled comparison of three post-graft environments, we found that graft success did not vary significantly among the treatments (Table 1). Graft success in a greenhouse, in a poly-covered lathhouse or outdoors was 90% or better. Over several years of experiments, however, we observed that success of lathhouse-grown grafts was always equal to or better than the greenhouse-grown grafts. The lathhouse-grown grafts generally grew slightly less the first season after grafting. This appeared to be due to the lower light in the lathhouse resulting in reduced photosynthesis after graft union formed. Grafts grown outdoors in full sun grew as well as the greenhouse-grown grafts when differences in scion size were taken into account (Table 1). Thus, production costs may be decreased by using less heat and less expensive structures, and higher yields may occur as well.

2) Reducing Water Loss:

We tested the effects of polyethylene covers and antitranspirants on graft formation, with the purpose of reducing water loss from the scions. Groups of thirty grafts were either covered with poly (the entire group covered with a single sheet), the scions dipped in a film-forming antitranspirant or left untreated. All treatments were grown in the greenhouse. Graft success and scion growth were about the same in all three treatments (Table 2).

3) PGR's to Stimulate Cell Division:

Plant growth regulators frequently stimulate increased cell division of plant tissues. We tested two synthetic auxins, indolebutyric acid (IBA) and naphthaleneacetic acid (NAA), a synthetic cytokinin, benzyladenine (BA) and a gibberellin (GA_3).

IBA consistently increased graft success.

The scion bases were soaked for three minutes in the appropriate concentration of chemical dissolved in 20% ethanol. At 1 mM (200 ppm) IBA and 1mM (225 ppm) BA, graft success was significantly greater than the control (Table 3). The effect of IBA was consistent over several years, that of BA less so. At low concentrations, about 20 ppm, NAA also increased graft success, but was toxic above that level. The gibberellin was toxic at all concentrations tested.

4) Remove Rootstock Buds:

One possible way to speed callus development at the graft is to remove the buds on the rootstock. We reasoned that with fewer growing points, there should be increased translocation of organic compounds to the few remaining sites of active cell division, including the cambium and the graft union.

Rootstock bud removal had only slight effect on graft formation.

Table 1. Effect of post-grafting environment on development and first year scion growth of Colorado blue spruce grafts. As the scions on the outdoor grafts were smaller initially, terminal length was shorter as a result. To take this non-treatment effect into account, scion growth was calculated to normalize scion size[Z]

Treatment	Successful grafts[Y] (%)	Terminal length (mm)	Scion growth[X] (mm-cm^{-3})
Greenhouse	97 a[x]	71 a	70 a
Lath house	100 a	59 b	58 b
Outdoors	90 a	56 b	70 a

[Z]Means separation in columns by protected LSD, 5% level.
[Y]Values based on 40 grafts per treatment.
[X]Total scion growth length per cubic centimeter of scion stem volume.

Table 2. Effect of postgraft polyethylene covering or film-forming antitranspirant treatment of the scion on development and growth of Colorado blue spruce grafts in the greenhouse.[Z]

Treatment	Successful grafts[Y] (%)	Terminal length (mm)
Control	82.5	55
Polyethylene	85.2	40
Antitranspirant	83.0	54

[Z]Means not significantly different at the 5% level.
[Y]Values based on 30 grafts per treatment.

Rootstock buds were removed either by hand or bud growth was retarded by the use of dikegulac, a plant growth retardant. Unfortunately, Norway spruce has an ample supply of latent or adventitious buds. As a result, bud removal was required weekly in order to elicit a significant reduction of bud growth on the stock. There was only a slight effect of this treatment on graft formation (Table 4). Dikegulac had similar, limited effects.

5) Root Warming:

Warming the roots enhances growth of some plants. This treatment could stimulate production or translocation of plant hormones from the roots and possibly result in more cell division at the graft union even though the shoot remains dormant. We tested the effects of root warming on graft formation of plants in the lathhouse. Plants in one treatment were held at ambient temperature; in the other treatment the roots (in containers) were placed in a medium at 70 F immediately after grafting. Graft success of the treated grafts was 52%, of the controls, 90%.

Root warming appeared to be detrimental to graft success.

6) Photoperiod:
Photoperiod often has profound effects on plant growth. However, graft success under long photoperiod was the same as the controls grown under ambient (January) short photoperiod.

As a result of these studies, we suggest that production of grafted Colorado blue spruce in the Willamette Valley can be improved simply and economically by using dormant rootstocks and overwintering the grafts in unheated structures, or even outdoors. This practice eliminates the cost of heating and results in generally better graft success. Growers should test this procedure cautiously, placing a fraction of production in cold frames until they are confident of the merit of the system. An additional treatment which could be tested, also with caution, is to soak the scion bases in 200 ppm IBA for no more than three minutes. This treatment should be approached experimentally in order to determine whether production is

actually improved. Besides these treatments which appear to increase graft success, we have reported the results of several other treatments which appeared to have little potential for application.

Table 3. The effect of pre-grafting scion treatments of IBA, NAA, and BA on Colorado blue spruce grafts. (One mM of these compounds is about 200ppm.)[Z]

Growth regulator	Concentration (MM)	Successful grafts[Y] (%)	Terminal length (mm)
IBA	0.1	90 ab	53 bc
	1.0	93 a	58 ab
	10.0	20 c	38 d
BA	0.01	87 abc	54 abc
	0.1	93 a	50 bcd
	1.0	72 d	43cd
NAA	0.1	90 ab	55abc
	1.0	83 bc	67 a
	10.0	0 f	---
Control		80 cd	59 ab

[Z]Means separation in columns by protected LSD, 5% level.
[Y]Values based on 30 grafts per treatment.

Table 4. The effect of retarding rootstock development on grafts of Colorado blue spruce.[Z]

Treatment		Successful grafts[Y] (%)	Total growth (mm)
Lath house [X]			
Control		95.8 a	144 c
Disbudding	constantly	83.3	239 a
Disbudding	x 3	87.0 a	197 bc
Disbudding	x 2	91.7 a	165 bc
Disbudding	initial	87.5 a	175 bc
Dikegulac[W]	2000 ppm	56.7 a	199 bc
Dikegulac,	1000 ppm	100.0 a	172 b
Greenhouse			
Control		80.0 a	202 a
Dikegulac,	2000 ppm	70.0 b	191 a
Dikegulac,	1000 ppm	87.7 a	164 a

[Z]Means separation in columns by protected LSD, 5% level.
[Y]Values based on 30 grafts per treatment.
[X]Grafts on dormant rootstocks that were overwintered in a polyethylene-covered lath house.
[W]Dikegulac applied by submerging the shoot into the solution.

Acknowledgments: We wish to acknowledge the extensive cooperation and generous contributions of plant material by Verl Holden, who supplied the scions for these studies, and Kerwin Doughton, who supplied the rootstocks.

Additional reading.

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