The Culture of False Hellebore

Veratrum plants and seeds have winter dormancy which is relieved by cold. The germination behavior, storage life of seeds, requirements for nursery culture and possibilities of vegetative propagation are described in this article—also the habits of several species in the wild.

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Considering the extent to which several species of *Veratrum* are collected and used commercially, there is surprisingly little information in the literature concerning where, how or whether they could be grown as a cultivated crop.

Roots of the white false Hellebore (*V. album*), supplied mostly from Europe, have long been employed as an insecticide, though this use has diminished with the introduction of better chemical insecticides. The American or green false hellebore (*V. viride* (Ait)) has long been recognized as a drug plant.

Veratrum viride contains a complex of numerous alkaloids and glucosides, some of which have useful hypotensive properties plus others that are highly toxic. Due to the varying composition of this complex, the plant was not widely used in the medical profession. However, extensive research on the pharmacology of the individual components by the Riker Laboratories and earlier workers led to the introduction in 1950 of "Veraloid", a uniform mixture of the more hypotensive alkaloids. This work is well documented in the literature which is not cited here because it is outside the scope of this paper.

The taxonomic literature is replete with descriptions of the above-ground portions of *Veratrum* species and general descriptions of their habitats. However, little has been reported on the ecological factors responsible for their distribution, their feral reproduction, ontogeny or the morphological characteristics which would dictate methods of propagation suitable for culture. Agnes Arber's (1) book on the morphology of monocotyledons pictures the underground portions of *V. viride*. Youngken (6) studied the anatomy of *V. viride* and *V. Eschscholtzii* A. Gray and described distinguishing features in the roots.

The present investigations were confined to *V. viride*, *V. Eschscholtzii*, *V. fimbriatum* A. Gray and *V. Californicum* Durand. *V. viride* inhabits moist locations in the eastern United States where winters are severe. It is a pasture weed in some areas around Quebec, Canada, and in the New England States, and extends southward in the Appalachian mountains into North Carolina and Tennessee. There are anomalies in its distribution, however, which cannot be explained on the basis of climate, soils or moisture supply. Its alkaloid content is correlated positively with latitude.

V. Eschscholtzii, a species very closely related to *V. viride* and considered by some taxonomists to be a western ecotype of *V. viride*, is found in the Hudsonian Zone from the Bering Sea and

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coastal ranges of Alaska through British Columbia into the higher elevations of Washington and on Mt. Hood, Oregon, thence eastward into Idaho and Montana. It is confined to moist but well-drained sites within a rather narrow altitudinal belt from the timberline to slightly lower. Some of the author's observations covering the typical and some exceptional sites are quoted in Dr. Youngken's paper.

V. fimbriatum is confined to a narrow strip of coastal California from Ft. Bragg southward to Ft. Ross, a distance of only about 60 miles and one to three miles wide. It extends from sea level to a few hundred feet elevation. While its vegetative tops resemble those of the other species, its showy fragrant flowers and large succulent and wingless seeds as well as its adaptation to a special climate seem to indicate evolutionary changes not shared by any of the other species. The climate of its limited habitat involves moderate and very uniform temperatures. Mean daily maxima during June through November are within the range 61° to 65° F., and during December through February 51° to 59° F. Mean daily minima June through November are within the range 47° to 50° F., and during January and February 36.4° to 40.3° F. Light freezing in winter or day temperatures higher than 70° F., in summer are infrequent. The species' adaptation to the mild climate and long growing season have important implications with respect to possibilities of introducing it in to cultivation.

V. Californicum is well described in the literature. While the distribution is characteristically in moist locations at altitudes providing six months or more of snow cover, a number of strains were found at places near sea level where winters are mild. This variation was of little interest in the present investigations because the species lacks hypotensive alkaloids.

Sexual Propagation

Bailey's (2) comment that *Veratrum* is readily propagated by seeds or division is an oversimplification. Personal correspondence with people who have tried to grow it in quantity from seed indicates that the attempts have been partial to complete failures. Multiplication of the crowns is so slow that propagation by division is quite impractical.

Dormancy. The seeds and rootstocks of *Veratrum* have pronounced winter dormancy, requiring prolonged cold before resuming growth in spring. The seeds have embryo dormancy similar to that of many species native to cold climates. Relief from dormancy by "after-ripening" is accomplished by holding the rootstocks or seeds in moist aerated media at temperatures a few degrees above freezing. The optimum temperature and period vary by species and are somewhat correlated with the species' native habitats.

Youngken (6) reports obtaining only 8% germination during 11 months after planting untreated seeds of *V. viride*, and no germination of untreated *V. album* seeds within 15 months. *V. viride* seeds held for two months at a temperature range of 32° to 35° F. gave 28% germination within a year. By comparison with the results reported below, his treatment seems to have been far from the optimum.

In testing seeds of *V. viride* and *V. Eschscholtzii* from the 1949, 1950, 1951 and 1952 crops, their dormancy appears to be so alike that conclusions as to effects of treatments are probably equally applicable to both species. This in spite of greatly differing germination percentages due to the differing proportions of unfilled and insect-damaged seeds in the *V. viride* seedlots used.

Stratification at temperatures slightly above freezing provided partial relief of dormancy the second and third months, but on removing the seeds to growing temperatures, germination was slow and to low percentages. After four to four and one-half months' stratification at 35° to 40° F., the seeds germinated promptly in the laboratory. In many tests, half of the total germination was attained during the first five to seven days and was complete at three weeks.

Germination percentages of the various seedlots of *V. viride* ranged from 22% to 65%, while those of *V. Eschscholtzii* ranged from 40% to 85%. The non-germinating seeds of properly after-ripened *V. Eschscholtzii* were those unfilled, damaged by insects or attacked by fungi during the after-ripening and germination periods. But in some collections of *V. viride* seed, substantial numbers remained plump and apparently sound for months after the run of germination was finished.

The stratification temperature range of 35° to 40° F. was more effective than 40° F. and slightly higher for relieving the dormancy of *V. viride* and *V. Eschscholtzii* seeds. When after-ripening was completed, the seeds sprouted at the lower range.

Dormancy of *V. Californicum* seeds was similar to that of *V. viride* and *V. Eschscholtzii* but was relieved by somewhat shorter periods of low temperature. Three months at 35° to 40° F. was apparently adequate for complete relief of dormancy. 70% germination occurred in two weeks; 74% at four weeks after moving the seeds to 70° F. temperature.

A comparison was made of the dormancy of two strains of *V. Californicum*—one from populations growing at elevations of about 3,000 feet in the Bitter Root Mountains north of Greer, Idaho; the other near sea level in the vicinity of Portland, Oregon. After 80 days stratification in moist perlite at 35° F., the seeds from the "high altitude" strain had broken dormancy and about 80% had germinated at that temperature. Within a week after moving the seeds to room temperature, additional germination brought the total to 98%. None of the "low altitude" seeds had sprouted at 35° F., and only 25% of them sprouted during the ensuing month at room temperature. But when the non-germinated seeds were returned to temperatures of 40 to 44° F., they broke dormancy and germinated within a week after the second transfer to room temperature. Total germination of this lot was 93%. Thus it appeared that the strain which had become adapted to the region of mild winters had acquired seed dormancy, responding to higher temperatures than those favorable to after-ripening (and actual sprouting) of the high altitude strain.

The seeds of *V. fimbriatum* are radically different from those of the species previously discussed. Not only are they different as to their dormancy but also in size, form and storage characteristics. They are succulent (containing about 80% water) and are killed by drying. The required period of moist storage at low temperature varied by seedlot, but usually two to two and a half months at 40° to 45° F. was adequate for complete relief of dormancy. Subfreezing temperatures were not injurious but were less effective for relieving dormancy. Also temperature 35° F. was less effective than the 40° to 45° F. range for this species. Acid peat was better stratifying media than the alkaline vermiculite or perlite, molds being prevalent in the latter two media.

The dormancy of *V. fimbriatum* also differs from that of *V. viride* and *V. Eschscholtzii* in that germination of non-after-ripened seeds is slow but not permanently inhibited. In one trial of non-after-ripened seeds, 60% germination occurred during four months at room temperature. This percentage was not greatly different from the totals obtained in three weeks by after-ripened seeds.

Most of the trials of after-ripening of the several species were made at the temperature range 35° to 40° F., but sub-freezing temperatures also were tried. With *V. viride* constant sub-freezing temperature was entirely ineffective, and when temperatures alternated one week frozen and three weeks above freezing, the seeds failed to germinate promptly. However, seeds of *V. Eschscholtzii* transferred from 40° F. to sub-freezing and back every two weeks germinated about the same as from constant 40° F. stratification. No after-ripening occurred among seeds held in dry sand at subfreezing or at temperatures slightly above freezing.

Effects of Light on Germination. After ripened seeds of *V. viride* and of *V. Eschscholtzii* were sown in replicate in Petri dishes, four replications of 100 seeds of each being held in darkness and four in weak light at the same room temperature. The light intensity varied during the day, approaching one foot-candle at mid-day. The percentage means of germination at 16 days were:

	Light	Dark	Least sig. diff. @ 5%
V. viride	67.7%	57.5%	6.95%
V. Eschscholtzii ..	91.0%	81.0%	6.90%

The wings and outer seed covering are waxy, but apparently the failure of germination among dormant seeds is not due to impermeability. The seed wings do contain water-soluble germination inhibitor(s) which greatly retard germination of some species' seeds and prevent germination of others. However, the substances are not present in sufficient concentration to affect germination after stratification.

None of the following treatments was effective for obtaining germination of the dormant seeds: leaching, hot water, sulphuric acid, sodium hypochlorite, surface active agents, thiourea, dewaxing with acetone or hexane, nutrients or combinations of constant and alternating temperature.

In all of the species mentioned, saprophytic molds were common in the stratification media, but they seemed to live principally on empty or injured seeds. Fungicidal treatments such as Arasan, Dithane Z-78 and Parzate were not wholly effective; and 8-hydroxyquinoline benzoate in solution 1:1200 applied for 20 hours prior to stratification killed seeds of *V. Eschscholtzii.*

Storage Life. *V. viride* is subject to intermittent seed-bearing habits. A year of heavy crop is usually followed by five or more years of very scant bearing. Consequently the possibility of storing surplus seed is important to a production program.

There were rumors that *V. viride* is in the category of plants whose seeds must be sown immediately upon ripening; this did not prove to be true. Collections in the vicinity of Quebec in the fall of 1950 and 1951 were kept dry at room temperature for periods up to four months, then stratified at low temperatures for another four to four and a half months before sowing in Petri dishes. While some differences in germination percentages occurred, they were not related to the periods of storage.

Seed of the 1950 crop was stored, sealed and unsealed, at room temperature and at approximately 40° F. for testing at the end of one and two years. Moisture content of the seed at the beginning of storage test was 7.9%. Unfortunately the stratification treatments immediately preceding the periodic sowings were not standardized, though they were uniform for all lots represented in each test. The germination percentages attained at three weeks in the germinator were as follows:

Two months dry storage plus 4½ months in moist sand and peat, at temperature range 35–40° F. Total germination = 30%.

Twelve months dry storage plus 4 months in moist vermiculite at approximately 40° F. The obviously empty or insect-damaged seeds discarded from the test samples.

	Sealed stg.	Unsealed
Room temperature storage	0%	0%
40° F. storage	17%	12%

Twenty-four months dry storage plus 4 months in moist perlite at 35° F., then germinated in light.

	Sealed stg.	Unsealed
40° F. temperature storage	46%	2½%

In the above tests many of the nongerminating seeds from the cold dry storage lots remained plump and apparently sound well beyond the germination test period (storage-induced persistent dormancy?).

Thus it appeared that *V. viride* lost all viability during the first year of storage at room temperature, whether sealed or not; but if held sealed at 40° F. it may be kept for at least two years without loss of viability. When held unsealed at 40° F., it declined in viability by the end of one year, and only a small percentage of the seeds were germinable at the end of two years.

The higher percentage germination attained after two years (sealed at 40° F.) than at the beginning of the experiment probably was due to more effective stratification technique and to light used in the last germination test.

Storage of *V. fimbriatum* Seed. Storage of *V. fimbriatum* seeds is limited by the fact that they are succulent and that drying kills them. Attempts were made to hold these seeds in a moist but quiescent state by the following methods:

	Storage temperatures (a)	(b)	(c)
1. Submerged in water	25–30°	35–40°	70° F.
2. Moist, in CO_2 atmosphere	"	"	"
3. Moist, in nitrogen gas	"	"	"
4. In moist vermiculite (controls)	"	"	"
5. Damp seed sealed with air	"	"	"

At the end of two months when after-ripening should have been nearly finished in the control 4-b, part of the series were germinated on blotters in Petri dishes at two temperatures (in darkness)—at room temperature of 70° F. and outdoors where night temperatures ranged from 35° to 40° and those of days from 55° to 62° F.

Germinations outdoors were nearly as rapid and to significantly higher percentages than at the 70° constant temperature. The seeds from lots 2-b, 3-b and 5-a were dead. Control 4-b germinated 60% at constant 70° F., and 77% outdoors, the final counts being made at 14 days. Lot 4-a germinated 39% at 70° and 62% outdoors—the germination of this lot starting about a week later than in lot 4-b.

At the end of ten months of differential storage, all of the seeds were dead. The inert gases preserved them from decay but, as noted above, greatly hastened their death.

The test indicated no way of storing *V. fimbriatum* seeds for use the following year.

Emergence and Early Seedling Growth. Numerous greenhouse and nursery sowings made under a wide variety of conditions showed that *Veratrum* seeds are extremely susceptible to the depth and kind of covering material. The linear primary leaf emerges doubled over in the shape of an inverted U, and slight matting or crusting of the cover medium prevents the distal portion of the leaf from emerging to assume an upright position. These die at the top of the loop and soon die back.

In greenhouse cultures, clean sand cover 1/16″ deep permitted best emergence; and shallow cover with vermiculite or shredded spaghnum was nearly as good. In outdoor sowings of *V. Eschscholtzii*, failed stands were common in spite of unusual precautions. The most successful nursery sowing of this species was in the Wind River Valley of Washington. There the nurseryman sowed freshly collected seeds thickly on the surface of prepared beds and applied a thin covering of clean sand. Heavy snow followed shortly and laid at depths of four to ten feet during the winter. Emergence occurred just as the snow was melting, seedlings being up at one end of the beds when drifts of snow still covered the remainder. While the resulting stand was dense, it represented only about 10% of the seeds sown. Sowings of *V. Eschscholtzii* elsewhere resulted in poor to failed stands.

The large seeds of *V. fimbriatum* have more emergence vigor than those of *V. viride* or *V. Eschscholtzii* but are sensitive to cover material. In trials of sand, peat, vermiculite, perlite and shredded redwood bark in comparison with soil cover, surviving stands differed greatly. Cover materials which remained sufficiently loose to permit good emergence often gave stands representing half to three-fourths of the seeds.

Seedlings of this species as well as of *V. Eschscholtzii* were sensitive to sunlight, and, unless shaded, they turned yellow and the tops died back early in the season. The cost of providing special covering material and shade was partly offset by reduction in weeding costs. The peat was fairly effective in controlling germination and growth of weeds; and *V. fimbriatum* thrived in shade dense enough to repress weed growth appreciably.

The primary leaf attains full size quickly, but no other leaves appear during the first growing season. Development of roots and of a small bulb continues during the summer if light and temperatures are favorable to the top.

Nursery stand densities of 100 to 150 seedlings per square foot apparently were not limiting to growth. Sizes attained the first and second years by *V. fimbriatum* and *V. Eschscholtzii*, respectively, differed enormously. The very slow growth of *V. Eschscholtzii* seedlings is illustrated by the fact that 3,000 two-year-old seedlings plus their packing material were shipped in a one-pound tobacco can. Digging and transplanting them was exceedingly tedious.

In some instances, root diseases caused serious losses of *V. fimbriatum* nursery seedlings.

Vegetative Propagation

Veratrum is a monocot of the family Liliaceae, so its possibilities for vegetative propagation are distinctly limited. Monocotyledonous plants lack a continuous meristem as a sheathing cambium, and usually lack the ability to form callus tissue from which new roots might be expected to grow.

Crown Division. The general arrangement of the underground parts of *Veratrum* is that of an upright rhizome thickly set with whorls of fleshy roots and surmounted by a massive bulb-like crown bud. The bud consists of concentric fleshy scales which are basal remnants of the previous season's leaves. In the center of its base is incipient development of the second year's crown bud which is destined to form a shoot during the third season.

Meristematic activities are confined to an axial growing point at the junction of the rhizome and crown bud, where are initiated the new crown bud and root primordia in numbers characteristic of each species. Growth of new cortex and xylem moves the developing new roots in an expanding circle, and during the following growing season they emerge from the cortex to add another whorl of roots at the top of the root system. In some crowns of *V. viride* sectioned in August, the root primordia were in two concentric circles suggesting periodic initiation.

Numerous crown buds are initiated, but apparently the first one to develop exercises dominance, preventing development of the remainder. Thus so long as the plant remains vegetative the crown remains single. However, upon the advent of flowering the flower stalk occupies the central position on the rhizome, and one or several of the otherwise suppressed buds develop to form independent crowns and eventually make a forked rhizome.

If the apical dominance of the primary bud could be suppressed, it should be possible to have numerous new crowns forming annually and a practical mode of propagation by division of the clumps. Substances presumably having anti-auxin activity, such as triiodobenzoic acid and ethylene chlorohydrin as well as traumatic acid and phytohormones, were used to treat dormant rootstocks of *V. fimbriatum* and to spray the tops repeatedly during the growing season. The treatments did not stimulate multiple crown formation, but this may have been due to lack of knowledge of the proper dosage and proper time of application. Dr. Went (5) experimented with an electrically heated needle pushed up through the rhizome to kill the new crown bud. In one instance where the injury was placed just right and not too extensive, numerous new buds formed. Later a device was used to drive a "comb" of blunt needles horizontally into the crown at a level likely to destroy the new apical bud. Mr. Chabot (4) reported that in some plants sprayed the previous growing season with colchicine, numerous new crown buds formed in the vicinity of the growing point. Thus there is experimental evidence that *Veratrum* plants are inherently capable of prolific annual increase by multiple crown formation.

However, the natural habit is for the crown to remain single from the seedling stage until the first year of blooming. This span is not definitely known but is probably seven to ten years. Thereafter they bloom only in occasional years, and flowering may or may not be accomplished by doubling or tripling of the crown. Frequency of blooming varies greatly by species and by habitat. Areas in the Sierras densely populated with literally millions of plants of *V. Californicum* were cruised without seeing a single bloom. In other seasons, scattered plants were found where 5% or more of the plants were in flower. Mature plants of *V. fimbriatum* bloom more regularly on the average than do those of *V. viride* or *V. Eschscholtzii*, but in some locations blooming is rare, and rhizomes showing ten years quota of root whorls had not bloomed during that period.

The rhizomes accumulate a new layer of tissue at the top with its accompanying whorl of roots each year, and the oldest lower portions disintegrate and slough off. Leaf scars leave an annual ring, and blooming stalks leave a distinctive scar as well as a diversion of the rhizome axis. Thus the age and blooming history of the surviving portion of the rootstock can be read rather clearly. There is no way of telling, however, how long the sequence of top increment and bottom discard has gone on. Judging from the indicated frequency of crown doubling, some of the clumps of *V. Eschscholtzii* examined in Alaska must have been more than a century old.

Severed Crown Buds. Attempts to increase the number of plants by splitting the crown and rhizome vertically into halves or quarters were unsuccessful. The mutilation and transplanting shock caused malformation and limited growth of the leafy tops which emerged; and only that division which happened to contain the growing point with preformed crown bud developed into a new crown.

Extensive trials were made of entire crown buds severed horizontally to include some of the top of the rhizome. This method, if successful, would have some practical aspects. Where native plants are harvested for commercial use of the roots and rhizomes, one could well afford to sacrifice part of the tonnage by removing and planting back the crown buds.

The author's trials were made with the crown buds from dormant plants of the species *V. viride, V. Eschscholtzii* and *V. fimbriatum* during three years. A preliminary trial was run, starting with dormant plants of *V. viride* collected in the mountains of North Carolina. The entire rootstocks were held in moist material at 35° to 38° F. from late October 1949 till February 20, 1950, to relieve dormancy. Then the crown buds were severed to include about one-quarter inch of the top of the rhizome and planted in a greenhouse, some in pasteurized medium fine sand and some in a potting mixture of loam, sand and composted manure. The upper half of the bud was removed from part of each lot, the idea being to restrict the amount of leafy tops which would be produced. Trial of indole butyric acid and of "Rootone" also was included.

The tops emerged in four days and were well expanded eight days after planting. Roots were slow to appear, but the tops survived with good color and turgor during the ensuing three months when the plants were taken up for examination. About half of the total number had made roots, ranging from one to 15 per plant and of sizes from pips barely visible to some four inches long, well clothed with lateral rootlets. Rooting was more prevalent in sand than in the potting mixture; and the hormone treatments appeared to increase rooting, though the limited supply of plant material prevented enough replication to be sure of this. There was no callusing at the cut surfaces of the rhizome nor of the root stubs which it carried. In many cases it simply rotted away without affecting the actively developing area above it.

The next trial a year later involved 78 treatments, each with four replications of five plants. It included several species and strains, severing the buds before or after the dormancy-breaking cold storage period, phytohormones and fungicides alone and in combination, several planting media in the greenhouse and some outdoor plantings.

Emergence occurred in the greenhouse plantings two days after planting, and the leaves of *V. viride* were expanded within a week. The tops retained good color and appearance for several more weeks. Deterioration of the tops was first apparent as browning and die-back at the leaf tips and occurred earlier among the Quebec Canada strain of *V. viride* than in the North Carolina strain. *V. Eschscholtzii* from Alaska made only limited and abnormal growth of tops, both from the crown buds and from the entire plant controls. An explanation of this is given in a later discussion of a peculiar inhibition of growth of this species when transplanted.

The surviving plants were harvested about six months after planting. On the whole, rooting was less frequent than in the previous year's trial, and obviously was affected adversely by the greenhouse temperatures. The Quebec strain seemed more sensitive to the greenhouse temperatures than was the North Carolina strain. Only two out of 740 of the Quebec strain rooted in the greenhouse, whereas 27 out of 160 (17%) of them rooted in an outdoor plot in shade where cooler temperatures prevailed. An additional 20% of them were still alive in the outdoor plot, though not yet rooted. Seventeen percent of the plants from the North Carolina strain of *V. viride* rooted in the greenhouse. Their tops were somewhat smaller than the tops produced by entire rootstocks and the new crown buds were smaller, but there was no difference in the root systems of the two classes of plants. The old rhizomes and roots of the whole rootstock controls had rotted. The very low percentage survival destroyed the significance of the various other treatments involved.

Outdoor trials of crown bud propagation of *V. viride* were made in the vicinity of Quebec by Mr. Chabot (4) and Dr. Camp (3). The unpublished reports received by the author were rather incomplete, but apparently the results were not very favorable.

***V. fimbriatum* Crown Bud Propagation.** The concurrent trial of *V. fimbriatum* crown buds was made by planting the severed crown buds from freshly dug plants, their bases immersed overnight in water or in indole butyric acid solutions of various concentrations up to 100 mg./l., then planted in a prepared plot in their native habitat, 100 buds per treatment.

At the end of the ensuing growing season, part of the plants were dug up for examination and replanted. The percentages rooted ranged from 40% to 90% and directly correlated with the concentration of IBA used, 90% of those treated 100 mg./l. being rooted. Whereas crown buds three-quarter inch to one and one-half inches in diameter were planted, those produced were only one-quarter inch to one-half inch diameter.

The following year the question was investigated further, using concentrations of IBA 0, 100 and 200 mg./l., and planting 20 buds of each treatment at seven locations. Two of the locations were in sun and shade, respectively, at the native habitat about 60 miles south of Ft. Bragg, California, and the other plots were in the vicinity of Humboldt Bay which is considerably north of the native range but with very similar climate. These plots differed as to exposure and soil type. Each of the crown buds was measured to determine later whether rooting and survival was correlated with size.

V. fimbriatum differs from the other species in that the crown buds push above the ground surface in late autumn, rest briefly in midwinter, then grow furiously in late February or early March. The crown bud plantings made October 16th to 19th were inspected November 15th. At that time the numbers of buds which had emerged were definitely related to the IBA treatments. The percentage means were: untreated 10%, IBA 100 mg./l. 35% and IBA 200 mg./l. 58% and consistently in this order at all plots. However, the stimulation of early top growth was not followed by any significant effect on the percentages of plants emerging the following spring or on growth the following summer. In fact the 200 mg./l. treatment reduced the percentage of survival.

In the first spring after planting the severed buds, the tops grew about as quickly as and to the size of those from whole rootstocks; and the tops survived surprisingly long into the summer, supplied only with stored food reserves and water absorbed from the cut bases. Also the embryonic bud made considerable growth concurrently with top growth. But development of roots from the initials known to be present was very slow and many failed entirely. Where external roots did develop, they came so late that top activity was nearly finished for the season, and the new crown was so small and weak that a majority of them failed to come up the second spring. Thus the second year's survival became the criterion of real establishment.

Second year survival was in all instances of much lower percentages than from the transplanting of whole rootstocks, and was correlated with the species' preference for shade, cool temperatures and protection from wind. In the first trial, where 90% of the plants showed some rooting at the end of the first growing season (in sun), only a few appeared the second spring. In the series of seven plots having various soils and exposures, the second year survival ranged from 0% to 60%. At the plots within the native habitat, survival in shade was 27% and in sun 0%. At Arcata, north of Humboldt Bay, a shady site had 50% survival and a nearby sunny (and windy) site had 1½%. At the less favorable sites many of the whole rootstocks survived but with poor growth, yellowish-green foliage and short season of top growth. Transplanting trials of whole rootstocks at inland locations where summer temperatures were higher than in the coastal zone were unsuccessful, though coastal locations as far south as Moss Landing in Monterey County permitted good growth of plants kept in shade and protected from wind.

There was one promising hint of a solution to the crown bud propagation of *V. fimbriatum*. In addition to the mid-October series of crown bud plantings described above, a mid-September planting was made at the sunny and windy site north of Arcata. In the third growing season these had 80% survival. Possibly the factor responsible for the inhibition of new root growth is something that develops with the ripening off and development of dormancy at a critical period in the fall.

Inhibition of root growth has been noted in more marked degree in whole rootstocks of *V. Eschscholtzii* transplanted in autumn. Dr. Went (5) held dormant *V. Eschscholtzii* rootstocks at low temperatures for periods up to a year without ever bringing them to a condition permitting normal growth. In the author's trials involving transplanting *V. Eschscholtzii* short distances in its native sites in Washington as well as the moving of Alaskan plants to various presumably suitable sites, the tops continued to grow for two years from food reserves stored in the original transplant, but with little or no root growth.

The root initials which had developed the summer before transplanting grew further only to the extent of showing as a ring of "pips" at the top of the rhizome. The crown which had been about two inches in diameter when transplanted, finally consisted of two crown buds one-half inch in diameter. Similar effects appeared among plants of *V. Eschscholtzii* on Mt. Adams, Washington, when moved only a few feet. They survived for two years but made no new roots. However, several exceptions were found. Some of the plants moved from Alaska to a site in northern Washington in the fall made new roots two or three inches long by the following May. Also one plant transplanted in northern Washington while in bloom thrived the following year, though it was not examined for root growth. Dr. Went surmised that root growth of *V. Eschscholtzii* may depend on hormone-like substances supplied by the root tips which are lost in transplanting. Such an hypothesis would be compatible with the easy re-establishment of *V. viride* plants which have a profuse network of lateral roots clothing the portions ordinarily moved.

Bulbels. Occasionally flowering plants of *V. fimbriatum* were found to bear axillary buds or bulbels. Their occurrence was rather rare, but when a plant of this habit was found the bulbels were usually present on several stalks of the clump. They were more slender than crown buds but of similar structure, some of them being as large as a man's thumb. Since they were enclosed by the sheathing leaf bases, they were difficult to find until the stalks died in the fall, when the still green live buds protruded from the rotting leaves.

Attempts to use them as propagating material were mostly unsuccessful. One of them formed a more globose bulb having several roots but no leaves during the first year, and became a small entire plant the second year. Mr. Chabot (4) reported finding similar bulbels on flower stalks of *V. viride* near Quebec, Canada. These were on plants which had been sprayed with colchicine earlier in the season.

Fertility Responses. *V. viride* plants were grown as pot cultures in the greenhouse, with nitrogen, phosphorus and potash added singly and in combination. Two soils were used, one a naturally fertile sandy loam and the other a loamy fine sand of low cropping potential. The plants were indifferent to added phosphorus or potash, but nitrogen significantly reduced their growth. Suppression of growth by added nitrogen was more pronounced in the naturally fertile soil than in the poorer soil.

Conclusions

Veratrum of the several species studied could be grown from seed on a commercial basis. However, the cultural requirements are very exacting and the seedlings must be tended in a nursery under suitable conditions for a number of years before transplanting to fields. The larger-seeded *V. fimbriatum* is easier to grow than *V. viride* or *V. Eschscholtzii* but is exacting in climatic requirements.

Field plantings must be confined to locations where the species' climatic and moisture requirements are met. In most locations shade is necessary, either by artificial means or by other plants. This would increase production costs. The crop cycle from seed to harvest of roots large enough for suitable tonnage was not determined but is estimated to be at least ten years.

Propagation of *Veratrum* by replanting crown buds taken from harvested rootstocks would shorten the crop cycle. Further research is needed to learn the techniques for successful use of this method. The practice would involve sacrificing 25% to 35% of the harvest tonnage.

So long as native *Veratrum* rootstocks are available, it would be infeasible to grow them as a cultivated crop.

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