INFORMATION AVAILABLE FOR OTHER WESTERN SPECIES HAVING SUFFICIENT GENERALITY TO BE APPLIED TO DOUGLAS FIR SEED MOVEMENT PROBLEMS

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Introduction

I have been asked to indicate what information is available for other western species that might have sufficient generality to be applied to Douglas fir seed-movement problems. This requires some introductory comments regarding some of the principles of plant geography.

Climate is generally considered to have been of great importance in the evolution of plants and in the determination of their present distribution. Nevertheless, edaphic factors, genetic history and other influences must not be neglected merely because less well understood. Information about climate within the natural ranges of our species is certainly inadequate and our knowledge of forest tree interactions with climatic factors is very limited. For these and other reasons, as Lines (1965) notes, climatic matching of seed sources with planting sites is rarely possible. Nevertheless, attempts to fit the climate of seed origin to the climate of the planting site are necessary. Lines (1965) suggests this match may best be made between climatic types, since it is very difficult if not impossible to find exact climatic parallels.

In order to make some comparisons between other species and Douglas fir, one must accept the general importance of climate as a controlling factor in the distribution and growth of all forest trees and recognize that there have been many factors operating in the past to develop clines or ecotypes within most of the species of commercial importance in western North America. Any proposed extrapolation from results with one species to another must be approached with great caution. Responses to environmental factors are too incompletely known and there are other unknowns. Although climate is frequently poorly known and difficult to measure at the present time, it may be a helpful guide to seed movement when related to natural ranges. However, it is an insufficient basis for prediction. Callaham (1964) warns, "sympatric species will be similar, but not identical in inherent adaptations to the same environment. Limiting factors generally are not always the same for cohabiting species".

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Burley (1965) recently reviewed variation in Sitka spruce, and presented a general review of patterns of variation. Much of the difficulty, he thinks, can be traced to confusion in the use of such terms as cline and ecotype. After discussing these terms he concludes with the following:

> "Probably the most acceptable concept of variation in forest trees is that climate has a continous variation pattern and tree growth is related to climate. Individuals of a widespread species should show continous variability of inherent climatic adaption. Superimposed on this clinal pattern, discontinuities in environmental factors may produce distinct genetic changes which may be justifiably recognized as ecotypes; soil types in particular show abrupt changes. In addition, a clinal pattern with respect to one selection pressure may be superimposed on a clinal pattern with respect to another. Indeed, in the multidimensional interaction of plant and environment, the pattern is more complex and it is easy to visualize the type of situation in which a soil ecotype occurs within an altitudinal cline superimposed on a latitudinal cline. Furthermore, mutations occur that have no adaptive value and are subject to random genetic drift. Such complexity is difficult to analyse in one experiment even under uniform growing conditions, and it is unnecessary to force such variability into an artificial system of nomenclature. Langlet (1962) considered it sufficient to indicate the native locality, the provenance, since this defines all that is referred to; the variability can then be described in the 'non-coloured' terms of cline".

In general Burley seems to agree with others that clines and ecotypes are not mutually exclusive concepts.

<u>Seed Movement In General</u>

Based on a study of Scots pine, Wright and Baldwin (1957) stated "Collect seed from within boundaries of the geographic ecotype best suited to the planting area. This may permit the safe transfer of seed for several hundred miles or for only a few miles".

Most of the ecotypes recognized are climatic in nature, but there are edaphic ecotypes in some species. One may visualize some of the problems involved in applying this rule stated by Wright and Baldwin (1957) in the extensively mountainous and rugged western regions of North America. Not only are there far too few climatic data, but the existence and boundaries of ecotypes and the direction and gradient of clines in forest tree species are only beginning to be recognized and given proper study. Certainly the boundaries of any ecotypes that may be conceived to exist in any of our species are poorly delineated, and no one seems to know how far along any reputed clines in either direction one may move seed with impunity.

However, no one needs to be sure whether clines or ecotypes or both exist in a given species in order to understand the value of a thorough knowledge of the geography of a region and of the influence of topography on local climate in respect to seed movement problems. In a region such as ours, this should be self-evident. Phytogeographical information and an appreciation of plant association concepts may be very useful in recognizing sharp changes in clinal gradients or boundaries of ecotypes.

Distance of seed movement in miles is not really the question of importance, nor is change in elevation itself critical, but the effect of these changes on the local "total environment". That distance in itself is not the important factor is readily observed here on the Pacific Coast. One may move quite quickly into a different climatic region by going either east or west over coastal mountain divides, or through the lower mountain passes, and in so doing move from windward and wet to leeward and dry slopes. Local topography and nearness to the sea, elevation and slope gradients, as well as air mass movments and other features influence climatic patterns and gradients. The series of parallel ranges extending in some instances almost continuously from the Pacific Ocean to the Rocky Mountains, create very complicated environmental patterns. Movement across the ranges produces a much more rapid change in climate than parallel to them north or south on the same general slope.

Climate appears to have had a similar effect on the differentiation of many species in western North America. However, local geography, migration and genetic history, not to mention inherent species differences have created much complexity, and unsuspected capabilities doubtless lie hidden in the genes of our forest trees. The results of moving Eucalyptus and Monterey pine around the world should be sufficient evidence of this. Burley (1965) notes, however, that such successes do not prove that small movements will succeed.

Experience in Seed Movements with Some Western Species other than Douglas fir.

Unfortunately, there are very few data for those species with ranges most coincident with Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco in the Pacific Northwest, i.e. western hemlock, (*Tsuga heterophylla* (Rafn.) Sarg.) western red cedar (*Thuja plicata* Donn) and grand fir (*Abies grandis* Lind.). However, considerable data do exist for ponderosa pine (*Pinus ponderosa* (Laws) from studies made in the United States, and also if we can accept for our purposes work done with our species in other parts of the world, we can examine a number of provenance studies made with Sitka spruce (*Picea sitchensis* (Bong.) Carr. and lodgepole pine, (*Pinus contorta* Dougl.)

Ponderosa Pine

The most complete analysis of the provenance question in ponderosa pine appears to be that of Squillace and Silen (1962). They studied in some detail two provenance tests conducted in northern Idaho and in Oregon and Washington. The former was 45 and the latter 30 years old. Together these two early studies sampled nearly the whole range of the species . The results of their analyses proved the existence of inherited differences in height growth and these seemed to be correlated with various geographic and climatic factors of the seed source localities. Growth rates apparently increased clinally from east to west and from south to north in the eastern portion of the range. Some evidence of an altitudinal cline was observed, with increasing growth from high to low elevation. In the western portion of the range there was no strong latitudinal effect noted. Inherent differences were shown for a number of characteristics including diameter growth, survival and resistance to browsing.

Squillace and Silen (1962) observe that the warm climates of the west coast present a maximum opportunity for natural selection for growth rate and appear to have caused the evolution of a very rapid-growing, though least frost-resistant form. Some rapidly growing trees may fail completely in extreme environments, and of course this places a limit on whatever gains might be made through moving faster growing strains out of their natural limits. These authors note that the question "Can benefits be gained from choice of seed from non-local sources?" cannot yet be answered directly.

They do suggest that substantial increases in growth rate over local planting stock may be possible over much of the range of this species. However, they are cautious in recommending such moves because the limitations of the test prevented adequate comparisons and also possible gains, they note, must be weighed against the risks of poor adaptability. In conclusion they seem to think that as more understanding is obtained "moderate risks will be accepted for moderate gains as they are for agriculture".

Callaham and Liddicoet (1961) studied the growth of progenies of ponderosa and Jeffrey pines at 20 years of age at 3 different elevations and reported heritable differences in height and diameter associated with elevation of the seed tree. At the 960 ft. and 2730 ft. elevation plantations, the fastest growing progenies were from seed trees growing at 1000 to 2000 feet above sea level. They were taller than either high elevation or very low-elevation progenies. At the highest elevation plantation, 5,650 feet, low elevation sources seemed to be falling behind in height growth (perhaps as a result of reaching above the deep snow-pack?) and suffered most from lean and stem breakage.

When Wells' (1964a) subdivision of ponderosa pine is compared with that suggested for Douglas fir by Frothingham (1909), some interesting similarities are observed. This is particularly true if one appreciates the major difference in the distribution of the two species in the Pacific Northwest. Thus, Frothingham's five silvical regions: - North Coast, Sierra, North, Central and Southern Rocky Mountain Regions for Douglas fir may be paired with North Plateau, California, Northern, Central and Southern Interior ecotypes of ponderosa pine recognized by Wells (1964a). Wells (1964b) suggests that the isolation barriers responsible for these ecotypes were geographic for the most part, and proposes that various combinations of selection pressure (particularly that due to minimum winter temperature), geographic isolation, population density and reproductive isolation may be responsible for such genetic differentiation as has developed in ponderosa pine. Perhaps a study of a similarly large number of representative provenances of Douglas fir might provide evidence sufficient to justify recognition of an approximately similar number of ecotypes. These of course would not necessarily show coincident boundaries.

Squillace and Silen (1962) comment on the similarity in the geographical pattern for provenance data for ponderosa pine and that available for Douglas fir.

That failure to recognize provenance differences can be extremely important in ponderosa pine is illustrated by the experience in New Zealand reported by Thulin (1957). Here ponderosa pine seed from British Columbia was planted on sites better suited to more vigorous provenances from California. The cost of this error has been conservatively estimated as a loss in growth of seven million cubic feet.

Lodgepole Pine

This western species has an enormous range, equaling if not exceeding that of ponderosa pine and Douglas fir, but in contrast to these, it is centered to the north in British Columbia and Alberta.

Recent summaries of the silvical literature for this species are found in the work of Edwards (1954-55) and Tackle (1959). Edwards states "*Pinus contorta* is a polymorphic species differentiated into ecotypes which form an ecocline ranging from the coastal Shore Pine to the most continental form of Lodgepole growing east of the Rocky Mountains and distributed between 64 and 36 N. Latitudes". He reports that the early U.S.A. plantation experiments in the Rocky Mountains produced results tending to confirm the old rule "local seed is best", but also remarks upon the many evidences of the adaptability of the species.

Critchfield (1957) studied geographic variation in this species, giving major emphasis to comprehensive measurements of a number of morphological characteristics based on arboretum, plantation, and natural forest samples. He concluded that four regional forms merited recognition. These were *Pinus contorta* Douglas ex Louden ssp. *contorta*, confined to the Coastal region of maritime climate and known as shore pine; *Pinus contorta* ssp. *bolanderi* (Parl.) stat. nov., the Mendocino White Plains regional form from a very local situation in northern coastal California: *Pinus contorta* ssp. *latifolia* (Engelm. ex Wats.), stat. nov., the Rocky Mountain form, and *Pinus contorta* ssp. *murrayana* (Balif.) stat. nov., the Sierra Nevada form.

Roche (1962, 1963) studied the shore pine form and found evidence that did not support Critchfield's view that the Mendocino White Plains form deserved a special status. His measurements of a six-year-old lodgepole pine provenance trial at the Institute of Forest Genetics at Placerville, California, showed that coastal provenances, even in the dry, relatively unfavorable climate there, were markedly superior in height-growth to the inland forms as a whole. They were also taller than the progeny of Sierra Nevada seed sources from areas relatively close geographically to Placerville, but from higher elevations to the south. In this plantation, seed from the supposedly dwarf "bolanderi" form growing in the Mendocino region produced trees among the tallest in the plantation. Evidence that the growth vigor of the coastal form is strongly inherited is abundant in European experience. However, in some areas of Europe the coastal forms are not winter-hardy.

Feilberg (1964) noted that Barner, in Denmark, considered the Lulu Island form, from the Fraser River Delta in British Columbia, to be unsatisfactory for silvicultural purposes. This is emphatically confirmed also from experience in Britain (Aldhous). The much better performance of coastal lodgepole (or shore) pine forms from across the Straits of Georgia on Vancouver Island, both in growth-rate and form illustrate the fact that movement of seed even short distances in this species may be unwise if the local population is unproved. Lulu Island provenance is characterized by poor form, slow growth, and excessive and precocious flowering which can occur as early as two to three years of age.

Sarvas[2] has observed that seed movement from high elevations at southern latitudes to low elevations at far northern latitudes, represented for example by the use of Colorado provenances of several species in southern Finland, results in quite a difference in the quality (wave lengths) of the light climate, in addition to possible differences in temperature climate, and of course photoperiod. He suggests this might account in part for the poor growth of southern, high-elevation forms of Douglas fir and the Rocky Mountain form of Abies concolor in Finland.

In contrast, however, Lines (1965) cites the instance in which Japanese larch from an altitude of 9,000 feet and the latitude of Algiers is growing well in Britain.

Feilberg (1964) reported that in interior provenances of lodgepole pine such as those from the Cypress Hills of Saskatchewan, the Peace River, and the interior of British Columbia have produced trees of excellent form in comparison with those of coastal origins when grown either in continental Europe or in Britain. He adds, however, that some coastal provenances have improved with age. Early mistakes were made in Britain (FAO 1964) with respect to lodgepole pine in attempting to grow inland provenances in high rainfall areas, rather than the coastal origins now generally used in such regions. Aldhous[3] states that in the wetter, western parts of Britain, the coastal

1 Personal communication 1965 in Vancouver from John R. Aldhous, of Alice Holt Lodge, ENGLAND,

2. Risto Sarvas Personal Communication – Helsinki, 1964.

3. John R. Aldhous Personal Communication – Vancouver, 1965.

provenances give consistently better results than do interior, but in parts of eastern Britain some interior origins show superiority. Of the coastal provenances, some northern origins produce trees of better form, but seed sources from coastal Oregon and Washington are better volume producers.

The results of experience in planting lodgepole pine of various provenances in Europe seem to be consistent in demonstrating the need to recognize latitudinal clines on the coast and the differences between coastal and interior forms. We can expect that greater success in survival and growth will be obtained when the climate of the origin corresponds fairly well with that of the planting site. However, the fact that certain populations may possess heritable characteristics that are not immediately apparent in the local climatic environment, as illustrated in the instance of the Lulu Island provenance, should warn us to proceed with caution.

Sitka Spruce

Ruth (1958) indicates that Douglas fir becomes associated along the Pacific Coast with Sitka spruce (*Picea sitchensis* (Bong.) Carr.) beginning about at latitude 53° N. and extending south to California, and that as the climate locally becomes warmer and drier (especially eastward,) the proportion of Douglas fir in the stands increases. He does not report any geographic races in Sitka spruce and omits any discussion of the provenance problem. On the other hand he stressed the important roles that physiographic and edaphic factors play in the occurence of Sitka spruce.

Karlberg (1961) stated that the provenance problem in Sitka spruce is not so complicated as in Douglas fir, because Sitka spruce has a long, narrow, and limited range at low elevation.

At the present time, provenance studies in spruce in British Columbia are just getting underway (B.C.F.S. 1964), Clark (1965). Sitka spruce, however, because of its high yield and value has long been grown in Europe and there are provenance studies there to which we may direct our attention.

Sitka spruce is by far the most important introduction to West Norway from North America (Robak 1960). The importance of provenance in this species in Norway has been well recognized since the early work of Hagem and others about 35 years ago. Sea level collections from localities south of 54° N. in North American did not give good results at 60° and farther north in Norway. In more southerly regions, the seed had to be collected from correspondingly high elevations. The opinion was held earlier that the most important factor in seedling hardiness was the total sum of warmth required for complete maturing of the shoots. More recently, experiments have indicated that photoperiod sensitivity in Sitka spruce is closely related to the latitude of the seed origin (Vaartaga 1959). In nursery practice in Norway this fact creates a practical problem due to the fact that differences in latitude existing between climatically similar regions in Western North America and West Norway involve differences in day length. Sitka spruce seedlings in Norway nurseries given a shorter photoperiod than normal have escaped winter frost injury which severly damaged control plants. Fortunately as seedlings grow older, they lose their sensitivity to photoperiod, and this problem is not important in the field. Provenances now used are all from northern British Columbia or Alaska.

Sitka spruce is used in Norway for reforestation instead of Norway spruce on sites exposed to strong sea winds, but only on suitable spruce soils (Robak 1960). Robak makes the point that except for some areas in Great Britain, West Norway is the only area in Europe which supplies Sitka spruce with a fully adequate moisture supply. He states also that it is the only area in which Sitka spruce planting has been based exclusively on provenances which research has shown to be climatically suitable. In 1954 their own plantations of definitely known origins produced their first good cone crop. For the most part, the history of their plantations confirms the efficiency of the provenances chosen. Their plantations from northern provenances yield considerably less than the Washington origins used in parts of Denmark, Germany, and Great Britain, but they are completely frost resistant. In Robak's opinion, the frost sensitivity of Sitka spruce as a problem in European forestry is simply a question of provenance.

According to Karlberg (1961) most of the Sitka spruce seed that has been introduced into Europe has come from the state of Washington. He cites Opperman in 1929 as stating that in Denmark suitable results could be secured with provenances from as far south as British Columbia and Washington, but thatsuperior results had been obtained from a "Tongass" provenance at latitude 53° 33 min. N. This strain surpassed more northerly ones, from places with too short a growing season as well as southerly ones originating in places where the growing season is such that (in Denmark) height growth is checked by frost.

Changes in ideas in Denmark seem to have occurred from time to time and Karlberg reports that Danes have preferred in some instances Washington provenances, rather than those from the Queen Charlotte Islands of British Columbia, because in some places the latter provenance flushes early and suffers from spring-frost injury. Also some of the Queen Charlotte strains have proved to have too many slow-growing, poorly-formed individuals which bear cones precociously. Karlberg suggests that some of these may be the result of collecting cones from poorly-formed phenotypes. In Jutland, provenances from Washington are reported to suffer from autumn frosts and winter cold, so that the Queen Charlotte provenance is preferred in this district of Denmark. He believes that the considerable local variations in climate in Denmark may account for the controversies over suitable provenances. He also, quite properly, notes that the Queen Charlotte Islands and the State of Washington comprise rather large and mountainous areas and it is quite essential to know more precisely where the seed has been collected.

It is obvious that not only for Sitka spruce, but for all species, provenance descriptions must be much more precise, not only in terms of geography and site conditions but with respect to the number, and phenotypic character of the trees from which cones are collected.

Schober (1962) has reported on provenance tests in Sitka spruce which were established in Germany in the early 1930's. Provenances represented included Alaska, Queen Charlotte Islands, B.C., Washington, Oregon, and California. The first two are considerably more resistant to winter cold and late and early frosts than are the others.

In a series in which the California provenance was not included, the Washington provenance, located on the west side of the Olympic Mountains, proved most productive and the Alaskan the least. In a 35-year-old series, in which the Alaska seed source was not included, a Washington provenance again produced the highest yield, followed in decreasing order by the Queen Charlotte Islands, Oregon, and California provenances. Depending upon local climate for this part of Germany, either Washington, British Columbia, or southern Alaska provenances were recommended.

Aldhous (1962) has reported on the first three years' growth in several nurseries in Britain of 12 provenances of Sitka spruce that ranged from 61 N. to 43 N. from Alaska to Oregon. In general, the northern origins grew less, but were more cold resistant. Growth in height was proportional to length of the growth period, and the more southerly provenances grew later into the fall. Several nurseries at different latitudes were involved and at Wareham, in Dorset, the most southerly site, plants from the southern latitudes (49 to 43) grew faster relatively to those from farther north, than did similar seedlings in the two northern nurseries. He suggests that this may have been due to a response by the southern provenances to the higher temperatures at Wareham, rather than a response by the northern provenances to photoperiod at the northern nurseries.

In these studies, Aldhous (1962) found that seedlings from Sooke on Vancouver Island, B.C. produced greater height growth than any other origin including some within 40 miles of Sooke. The reason for this superiority is not clear.

Aldhous[1] believes coastal Douglas fir to be less sensitive to latitudinal differences than Sitka spruce.

Burley (1965) summarizes experience in the United Kingdom with Sitka spruce provenance trials by noting that Oregon and California provenances have been heavily damaged by frost, but that provenances from British Columbia and Alaska have generally been more resistant. In the same regions, as we have noted earlier from the work of Aldhous (1962), a cline for decreasing

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1. John R. Aldhous. Personal Communication 1965. Vancouver.

vigor from Oregon to Alaska is shown. A somewhat similar pattern was also demonstrated in Germany by Schober (1962) it may be recalled.

Lines (1965) in discussing the adaptation of various provenances of Sitka spruce to areas in Britain, notes that a fairly good match of climate can be made between the Queen Charlotte Islands and the Borders except for the fact that spring frosts in the Queen Charlottes are relatively unimportant, but can be very severe in parts of the Border area. For this reason, he suggests that the Queen Charlotte Islands provenance may be less well-adapted to growing on a site liable to frost in this region, than a provenance such as that of Juneau, Alaska which is at the head of a fiord, next to a glacier. This may remind some of you of the well known preferences in some parts of Europe for the Darrington, Washington and similarly-located provenances of Douglas fir.

In connection with photoperiod, Lines (1965) stated that differences show up most strikingly in times of cessation of growth, and that the early cessation of growth in northern provenances appears to be controlled by photoperiod rather than by temperature, and is the principal reason why southern provenances seem to be preferred unless frost susceptibility is a problem. He notes, however, that flushing is not always under photoperiodic control and indicates that this is true for Douglas fir and Norway spruce. In Britain, considerable differences in flushing dates have been noted between provenances of the same latitude. He says that provenances on the oceanic fringe flush later than more continental ones, perhaps because the former are more adapted to a climate with slowly rising spring termperatures, with frequent reversions to colder weather, whereas the latter undergo a later but more rapid, constant rise in spring temperature. We know from local experience here in British Columbia that similar flushing differences occur in the nursery, and in the field in Douglas fir, even where important differences in elevation may not be involved. Individual tree differences in flushing dates in one locality may be considerable, as is evident from the studies of Dr. B. G. Griffith, at the U.B.C. Forest in southern British Columbia.

As Burley (1965) states, provenance testing may well have to become more refined once the general pattern of variability is known and once the broad region suitable for seed supply has been approved. However, as others have noted, (Callaham, for example) provenances tests can become exceedingly expensive, so that screening methods and correlations established through nursery and growth-chamber studies should be used in connection with the essential, well-designed and carefully executed provenace trials that will be required in the field.

Species other than these discussed above, such as western hemlock, grand fir, and western red cedar are of interest to European forestry, but reference in the literature to provenance research and published data are rare for these trees.

Summary and Conclusions

Several summary statements relating to forest tree seed movement based largely on European experience have been published recently.

Wiersma (1962) notes that certain generalizations may be possible if one limits the area concerned to that between 30° and 60° of latitude. He suggests that normally a tree will tolerate a movement up to 150 or 250 km north or southwards or up to 200 meters of elevation in either direction. He also states that in moving a species it may be possible to compensate for the change in latitude by a change in altitude. He suggests that in the Northern Temperate Zone a displacement of one degree to the north can be corrected by a reduction in altitude of 100 meters. That there are many exceptions to this rule, caused by volume of mountain range, character of the climate, etc. he acknowledges.

Rohmeder (1965?) states that in respect to heat factors, a difference of 1000 meters in elevation may be the equivalent of a horizontal movement in a north-south direction of about 800 kilometers. He indicates that the place of origin of seed as a rule should be no more than 300 meters higher or lower than that of the planting site. Based on experience in Europe with native forest tree species, he states that lower elevation origins are more vigorous than higher elevation seed sources, but when these are moved to higher elevation they do not maintain this greater vigor for long due to cold injury or snow-fall damage. High elevation provenances moved to lower elevation plantation sites retain the genetically fixed, short growing period and do not take advantage of the more favorable lowland climate.

It should be obvious to the forester well acquainted with forest geography in western North America, that these generalizations must be considered only broadly useful guides. We should make every effort to add to our information concerning local climatic, edaphic, and biotic environmental factors and study the variability of our forest tree populations thoroughly.

There is some evidence from a number of species that the length of growing season and minimum temperatures are important and the photoperiod and precipitation pattern may be influential. It appears that whereas climatic analogues may be useful, soil factors and often unknown genetic and historical factors may be crucial in effecting successful establishment or growth.

Interior or continental forms and high elevation seed origins when moved to milder sites to the south, or to lower elevations, or to an oceanic, coastal climate may flush too early or fail to grow normally, perhaps for lack of normal winter temperatures. In some species at least, cessation of shoot growth in the fall seems to be under strong genetic control, and may often prevent utilization by the plant of supposedly more favorable climates.

On the other hand, coastal, maritime or low elevation provenances when moved to the north, or to higher elevations or to continental, interior sites may fail to be sufficiently drought resistant or winter cold hardy, or may continue growth late in the season and be damaged or killed by autumnal frost.

Yet, there have been instances where such "predictable" changes have not occurred and such seed movements have even resulted in moderate or greater increases in yield. In other words, we just don't know enough. At least some risks in the interest of gaining knowledge seem to be worth taking, but they only seem likely to be worth the gamble if we make sure our records are better than adequate, enduring, and retrievable, and if we do our best to see that our plantations survive preventable damage long enough to show results.

In closing I would like to quote from Haworth (1965) who said in discussing "Some problem Areas in the Relationship between Government and Universities", "How can that particular piece of basic research possibly ever have an application?...is not a proper question;...what is important, even from the standpoint of ultimate application, is the total understanding that grows out of many experiments analyzed and interpreted as a whole".

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