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The effect of growth on cone crops in Norway spruce (*Picea abies* (L.) Karst.)*

INTRODUCTION

It is obvious that producing reproductive structures must entail a considerable metabolic effort at the expense of growth. An estimate of this effort for Norway spruce is presented separately (Chałupka et al., 1975). On the other hand one can expect that stronger, better growing trees will produce more seed. It has been established that there is a positive correlation between cone crop and the dominant height of the stand (Sarvas, 1968), or the diameter of trees (Tyszkiewicz, 1949; Hagner, 1958; Uskov, 1962; Eliason and Carlson, 1968). Trees belonging to the 1st and 2nd biological class of Kraft have had 80% of all the cones in the Picea abies stand (Messer, 1956). Similar is the case with the grafts of *Picea abies*, in which the flowering intensity increased with graft height (Remröd, 1972). In *Pinus elliottii* Engelm. it has been observed that also the size of the branches (length, thickness at base) was greater in the more abundantly flowering trees (Varnell, 1970). On the other hand in *Pinus ponderosa* Laws. there is no relation between tree size or annual increment and the cone crop (Daubenmire, 1960).

There is some doubt about this correlation of fecundity with growth characters, because we know that sometimes there exist very fecund trees which are poorly growing, defective or even dwarf. It appears that in these trees all metabolic effort goes into flowering and fruiting and little or none into growth. There seems to be an inbuilt mechanism in many plants that divers all effort to flower and seed production whenever the environmental conditions are such that death of the plant appears to be imminent. This is evolutionarily quite understandable and the existance of individuals which have this mechanism operating to an excessive degree can be expected.

When establishing forest seed orchards we need clones which are fecund, yet we do not want the individuals that produce seed to an execes-

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sive degree, inhibitive to growth, in case the progeny might inherit this undesirable trait. G e r h o l d (1966) has reported that the practice of collecting cones on young *Pinus silvestris* L. Christmas tree plantations has produced after three generations a population flowering intensively and precociously. The parallel reduction in growth need not be a problem in Christmas tree plantations but it will be in seed orchards the purpose of which is to produce seed from which intensively growing trees will be obtained. For the establishement of seed orchards we select plus trees that have attained considerable dimensions and we hope the clones will have a fast growing progeny. Yet we also require that it should yield the progeny abundantly. Are these two requirements reconcilable? Are we not selecting against fecundity when we select for growth?

The aim of the study reported here was to establish the extent to which the cone crop is dependent on the growth characteristics of a tree.

MATERIALS AND METHODS

Cone collections were made on mature felled trees of *Picea abies* (L.) Karst. in 1968 from the Beskid region and in 1971 from northern Poland (Tab. 1). In 1968 there was a poor cone crop and in 1971 a good one. In

Table 1

Localities where cones were collected

Year	Forest District	Compt.	Lat. N	Long. E	Alt.	Age
1968	Rycerka	53	49°30′	19°00′	700	85
1968	Istebna	80b	49°34′	18°56′	580	100
1968	Wisła	83	49°37′	18°56′	540	55
1968	Bystra	56h	49°39′	19°46′	500	80
1968	Szczyrk	156	49°41′	18°59′	600	70
1968	Orawa	54	49°34′	19°32′	1000	110
1968	Zawoja		49°36′	19°33′	700	80
1968	Węgierska Górka	163	49°34′	19°01′	600	95
1968	Ujsoły	102	49°29′	19°12′	850	95
1971	Supraśl	70a	53°15′	23°20′	170	140+80
1971	Sokółka	252j	53°15′	23°30′	160	150
1971	Złota Wieś	108b	53°18′	23°16′	160	130
1971	Płaska	103d	53°54′	23°17′	130	95
1971	Serwy	289h	53°55′	23°10′	140	105
1971	Gołdap	281f	54°20′	22°20′	205	100
1971	Szczebra	128d	53°55′	22°55′	140	110+80
1971	Borki	146a	54°10′	22°10′	200	100
1971	Białowieża	429Bb	52°40′	23°55′	175	120
1971	Hajnówka	262Dd	52°45′	23°37′	180	130
1971	Zwierzyniec	473Cd	52°40′	23°45′	175	130
1971	Maskulińskie	249h	53°35′	21°45′	120	130

each of the 9 Beskid and 12 northeastern populations 10 trees were selected randomly, felled, measured accurately and all cones were collected. In 1968 increment cores were taken with a Pressler borer and in 1971 a disc of wood from mid-point on the length of the stem. The following data was collected for each of the trees:

Generative characters

1. Total weight of cones after seed extraction [g],
2. Number od cones,
3. Total weight of dewinged seed [g],
4. Number of seeds in thousands,
5. Weight of 1000 seeds [g].

Growth characters

1. Tree height [m],
2. Breast height diameter — DBH [cm],
3. Diameter at mid-point on the length of the tree — DMH [cm],
4. Tree volume [m^3],
5. Length of the crown [m],
6. $\frac{\text{Length of the crown}}{\text{Tree height}}$ — (crown proportion),
7. $\frac{\text{Tree height}}{\text{DBH}}$ — (taper),
8. $\frac{\text{DMH}^2}{\text{DBH}^2}$ — (form factor),
9. Increment over last 30 years [mm],
10. Increment over last 20 years [mm],
11. Increment over last 10 years [mm],
12. Increment in 1966 [mm],
13. Increment in 1967 [mm],
14. Increment in 1968 [mm],
15. Increment in 1969 [mm] — 1971 collection only,
16. Increment in 1970 [mm] — 1971 collection only,
17. Increment in 1971 [mm] — 1971 collection only.

A first look at the data suggested that there exist some positive correlations between the generative and growth characters on a within population basis, but having only 10 trees per population these correlations were not significant. It was not possible to pool all the trees from different populations because of differences in age, size of the trees, crop etc. Thus correlation coefficients (r) between the generative and growth characters were calculated separately for each population, and converted to Fisher z values by the formula

$$z = {}^1/_2 \ln \frac{1+r}{1-r}$$

Then an averaged weighted value of z was calculated from all the populations in each region (9 for Beskid and 12 for NE Poland), and converted back to the correlation coefficient r, which was estimated on the basis of $[\Sigma (n-2)]-1$ degrees of freedom (that is $9\times(10-2)-1 = 71$ for the Beskid region and $12\times(10-2)-1 = 95$ for the northeastern region). The actual values of r were no greater than initially but their significance improved markedly by this procedure since they were based on more degrees of freedom. The z transformation was necessary because correlation coefficients do not have a normal distribution and therefore cannot be directly averaged (Fisher, 1956).

RESULTS

The averaged correlation coefficients are presented in Tables 2 and 3 and those between generative characters and girth increments are also plotted in Figs. 1 and 2.

The most obvious result is that there is full agreement between the data for total cone weight, total cone number, total seed weight and total seed number. These are in fact one character which can be referred to jointly as cone or seed crop.

It is generally related to girth increment over the last few years. The correlation with the last 10 years is better than the correlation with the last 20 or 30 years (Fig. 1 and 2). Of the individual years preceding

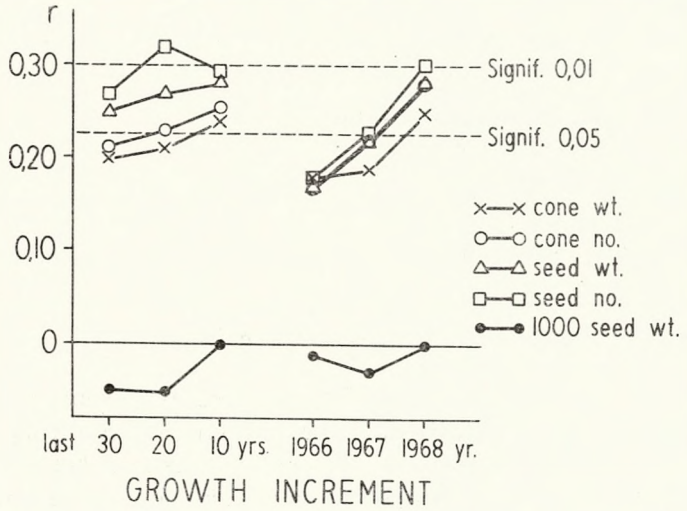

Fig. 1. Value of the mean correlation coefficient between generative characters and radial growth increment in the years preceding cone collection made in late 1968 in the Beskid region

cone collection, in a poor cone crop year the correlation is best with the increment in the year of cone development (Fig. 1) and in a good crop year with the increment in the year of flower initiation, while during the year of cone development the correlation of increment with cone crops declines markedly (Fig. 2). It becomes negative in a very good cone crop year (Chałupka et al., 1975).

The weight of 1000 seeds is however a totally different character, unrelated to growth increment (Fig. 1).

Characters of tree size (height, DBH, DMH, volume) correlate positively and highly significantly with the cone and seed crop in both the studied years and regions. To a lesser extent this is also true of crown length (Tab. 2 and 3). The weight of 1000 seeds is independent of the tree size in a poor seed year (Tab. 2).

Table 2

Mean correlation coefficients (averaged through Fisher z-transformations) between generative and growth characters for mature Norway spruce from the Beskid region (0.23 signif. at 0.05 level; 0.30 signif. at 0.01 level)

Growth characters	Generative characters				
	cone wt.	cone no.	seed wt.	seed no.	1000 seed wt.
Tree height	.32++	.32++	.28+	.28+	.04
DBH	.32++	.30++	.31++	.31++	.00
DMH	.35++	.37++	.37++	.37++	.12
Tree volume	.31++	.33++	.34++	.33++	.11
Crown length	.24+	.27+	.23+	.24+	−.04
Crown proportion	.11	.14	.11	.12	−.02
Taper	−.22	−.19	−.20	−.22	.08
Form factor	.03	.11	.08	.07	.18
Increment over last 30 yrs	.20	.21	.25+	.27+	−.05
Increment over last 20 yrs	.21	.23+	.27+	.32++	−.05
Increment over last 10 yrs	.24+	.25+	.28+	.29+	.00
Increment in 1966	.25+	.28+	.28+	.30++	.00
Increment in 1967	.19	.22	.22	.23+	−.03
Increment in 1968	.18	.17	.17	.18	−.01

Proportion of the tree height occupied by the crown, and the stem form factor are unrelated to the generative characters. The taper of the stem has a negative correlation with the cone and seed crop, highly significant in a good crop year and almost significant in a poor crop year (Tab. 2 and 3). This indicates that more robust stems tend to have more cones than the slender stems. This character is not related with 1000 seeds weight.

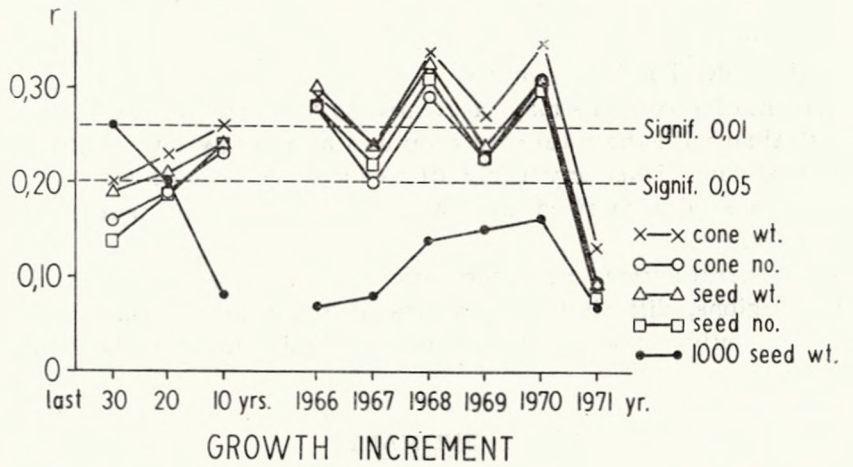

Fig. 2. Value of the mean correlation coefficient between generative characters and radial growth increment in the years preceding cone collection made in late 1971 in northeastern Poland

Table 3

Mean correlation coefficients (averaged through Fisher z-transformations) between generative and growth characters for mature Norway spruce from the region of northeastern Poland (0.20 signif. at 0.05 level; 0.26 signif. at 0.01 level)

Growth characters for	Generative characters				
	cone wt.	cone no.	seed wt.	seed no.	1000 seed wt.*
Tree height	.41++	.40++	.38++	.37++	.30
DBH	.40++	.37++	.36++	.34++	.21
DMH	.48++	.48++	.48++	.45++	.22
Tree volume	.48++	.48++	.48++	.45++	.20
Crown length	.23+	.21+	.24+	.21+	.23
Crown proportion	.07	.06	.10	.08	.19
Taper	−.27++	−.26++	−.26++	− .24+	−.06
Form factor	.08	.10	.10	.12	.05
Increment over last 30 yrs	.20+	.16	.19	.16	.26
Increment over last 20 yrs	.23+	.19	.21+	.19	.20
Increment over last 10 yrs	.26++	.23+	.24+	.24+	.08
Increment in 1966	.29++	.28++	.30++	.28++	.07
Increment in 1967	.24+	.20+	.24+	.22+	.08
Increment in 1968	.34++	.29++	.33++	.31++	.14
Increment in 1969	.27++	.23+	.24+	.23+	.15
Increment in 1970	.35++	.31++	.31++	.30++	.16
Increment in 1971	.13	.09	.08	.08	.07

* Values of reduced reliability due to presence of trees with no cones.

DISCUSSION

The data presented indicates that in a mature stand large sized trees with good growth increment are the ones that produce most cones and seeds. The general correlation of fecundity with growth is positive. A good or even a medium cone crop will reduce girth increment in the year of cone development, particularly on the more fecund trees but over many years this loss is more than compensated by better growth of these trees. Thus a selection of plus trees for growth will also be a positive selection for fecundity.

Weight of 1000 seeds may be related to tree size but the correlation is weaker than with the total seed crop and apparently only when the crop is a good one. Thus any early differences in growth of the progeny related to seed size need not be related to growth potential of the maternal trees.

The general agreement of the basic result for the two widely different spruce regions, differing also in size of the cone crop at the year of collection, only serves to underline the significance of the conclusions drawn.

SUMMARY

In the Beskid region during a poor cone crop year (1968) and in north-eastern Poland during a good cone crop year (1971) 10 random mature spruce (*Picea abies* (L.) Karst.) trees were felled per stand in 9 and 12

stands respectively. All cones were collected and the trees were measured accurately. Correlation coefficients between generative and growth characters were pooled over all the stands in a region using the Fisher z — transformation. The results indicate that cone and seed crop is positively correlated with characters of tree size and radial growth increment. Increment in the year of cone maturation is affected negatively by the cone crop, particularily in the more fecund trees but this is more than compensated by better growth of these trees over many years. Thus selection of plus trees for growth is also positive selection for fecundity. The weight of 1000 seeds is not correlated with the tree size in a poor seed year.

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WŁADYSŁAW CHAŁUPKA, MACIEJ GIERTYCH

Wpływ cech wzrostowych świerka (Picea abies (L.) Karst.) na obradzanie szyszek

Streszczenie

W roku słabego urodzaju szyszek (1968), w 9 dojrzałych drzewostanach świerkowych z Beskidów ścięto po 10 losowo wybranych drzew. Podobnie postąpiono w roku dobrego urodzaju szyszek (1971) w 12 drzewostanach świerkowych z Polski północno-wschodniej. W obu przypadkach ze ściętych drzew zebrano wszystkie szyszki, a same drzewa dokładnie pomierzono. Współczynniki korelacji między cechami generatywnymi a wzrostowymi dla poszczególnych drzewostanów zostały zsumowane według przekształcenia *z* podanego przez Fishera. Uzyskane wyniki wykazują, że urodzaj szyszek i nasion jest dodatnio skorelowany z wielkością drzewa i przyrostem grubości. W roku dojrzewania szyszek, szczególnie u silniej obradzających drzew, przyrost grubości ulega zmniejszeniu pod wpływem urodzaju szyszek, jednak ubytek ten wyrównywany jest z nawiązką przez lepszy przyrost tych drzew w ciągu lat upływających między kolejnymi, dobrymi urodzajami szyszek. Tak więc wybór drzew doborowych ze względu na dobre cechy wzrostowe jest jednocześnie pozytywną selekcją ze względu na płodność. W roku słabego urodzaju nasion, waga 1000 nasion nie jest dodatnio skorelowana z wielkością drzewa.

ВЛАДЫСЛАВ ХАЛУПКА, МАЦЕЙ ГЕРТЫХ

Влияние особенностей роста ели Picea abies (L.) Karst. на урожай шишек

Резюме

В год низкого урожая шишек (1968) в 9 древостоях в Бескидах было спилено по 10 случайно выбранных полновозрастных деревьев ели. То же самое было сделано в год хорошего урожая (1971) в 12 древостоях в северо-восточной Польше. С каждого дерева собраны все шишки, а деревья были тщательно измерены. Средние коэффициенты корреляции между вегетативными и генеративными признаками были высчитаны с помощью преобразования Фишера. Показано, что урожай шишек и семян положительно скоррелирован с величиной деревьев и их приростом в толщину. Прирост в год развития шишек находился в отрицательной зависимости от их количества, особенно у наиболее плодовитых деревьев, но эта потеря с избытком компенсируется лучшими приростами у данных экземпляров в менее урожайные годы. Поэтому селекция под углом зрения интенсивности их роста является в то же время положительной селекцией на плодовитость. Три высоком урожае вес 1000 семян положительно скоррелирован с величиной дерева, но при низком урожае связь между этими двумя признаками отсутствует.