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Estimation of cowberry (Vaccinium vitis-idaea) yields

JAANUS PAAL[1], TAIMI PAAL[2]

[1]Institute of Zoology and Botany, Vanemuise Str. 21, Tartu, EE-2400 Estonia
[2]Institute of Forestry and Nature Conservation, Rõõmu Str. 2, Tartu, EE-2400 Estonia

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Four methods of cowberry (*Vaccinium vitis-idaea* L.) yields estimation based on the principles of quantitative plant ecology are compared, and their accuracy and practical application are discussed.

Keywords: cowberry, *Vaccinium vitis-idaea*, berry yield, yield estimation methods, Karelia.

I. Introduction

The yield of wild berry plants is a very unstable parameter which is dependent to a large extent on the weather and habitat conditions, diseases etc. This causes a lot of practical difficulties in collecting representative yield data at a sufficiently high probability level. The lack of economic and statistically correct methods for these purposes has been much discussed in the Russian literature since 1965 (Krasilnikov & Nikitin 1965, Tyulin 1973, Cherkasov 1976, Kalinina 1980).

It seems that useful support can be obtained from certain principles and well-known methods of quantitative plant ecology.

II. Study area

The methods were tested and compared in the Kivach Nature Reserve, South Karelia, Russia. Three plots in Vaccinium-type pine forests, all on illuvial sandy podzols, were used. The sizes of the plots were different (0.7-2.0 ha), so that they must be taken to represent, in our opinion, the total area of the coenopopulation investigated in each case.

First plot: a flat plain with a pine stand of mean age 130 years, mean height 23.0 m, density 0.6 and projective cover of cowberry (*Vaccinium vitis-idaea* L.) 35%. Second plot: gently undulating lower slope of an esker, stand age 137 years, height 21.5 m, density 0.7, cover of cowberry 24%. Third plot: slope of southerly exposure, gradient 3-4°, stand age 142 years, height 24.0 m, density 0.8, cover of cowberry 41%.

III. Methods

Four methods for the estimation of cowberry yields were compared.

Method 1. A line was marked with sticks at intervals of 20 m along the longest axis through the centre of the plot. Numbers were then taken in pairs

Table 1. Mean yields of cowberry (g per m^2) according to the four methods of estimation. s— error of mean, m — accuracy (relative error).

Plot	Method	Number of subplots	mean	s	m, %
1	I	100	10.2	0.75	7.4
	II	170	9.2	0.76	8.3
	III	377	6.8	0.44	6.3
	IV	556	13.6	0.56	4.1
2	I	160	4.4	0.49	11.1
	II	187	6.0	0.68	10.9
	III	270	3.2	0.36	11.7
	IV	596	3.2	0.20	5.9
3	I	120	16.8	1.70	10.1
	II	157	11.2	1.36	12.1
	III	179	17.6	1.68	9.6
	IV	496	10.8	0.52	5.0

from the table of random numbers and used as coordinates for random points. The first number denoted the distance in metres forward along the line and the second number the number of metres to the right (even number) or left (odd number). When the random number was too large for the dimensions of the plot, it was ignored and the next number taken from the table. We then returned to the point where the 1st coordinate ended and repeated the procedure with the next pair of random numbers. When the plot was crossed but the number of points was still insufficient, the procedure was repeated backwards from the end of the line. Every point found was used as a defined corner for a block of four 1x1 m subplots, laid out in parallel to the line.

Method 2. The yield was picked between trees chosen by the nearest neighbour methods (Cottam & Curtis 1949, Pielou 1969). Random points were selected as in the first method, and the nearest neighbouring tree was then found and a transect of 0.5x0.5 m subplots was set up between this and the next nearest tree.

Method 3. This was based on the wandering quarter method (Catana 1963). A random tree was selected on the border of the plot and random direction across the plot was chosen from it and used to bisect an angle of 90°. Then the nearest tree inside the angle was found and the next one from that tree inside the angle, etc. Again transects of 0.5x0.5 m subplots were placed between the selected trees.

Although the nearest neighbour method and wandering quadrat method were introduced in quantitative plant ecology some decades ago, it is only now that they have been modified for use in estimating berry yields. These methods are normally used in plant ecology for analyzing the distribution of species or forest mensuration parameters, and we have simply borrowed the principle of randomization. The way of using the transects and the techniques of processing the data are specific to the estimation of resources.

Method 4. The random points and nearest trees were found as in Method 2. Then, starting from the given tree, four transects consisting of 0.5x05 m subplots were laid out in the four cardinal directions. The final point for each transect was the first tree growing in its path. Thus the transects were of unequal length, from 2-3 m to 50 m or more. This

Table 2. Comparison of cowberry yield data by two-factor analyses of variance. * = $p<0.05$.

Variation	Methods compared: II-III-IV			Methods compared: I-II-III-IV		
	Sum of squares	df	F	Sum of squares	df	F
Factor "plot"	969.77	2	47.82*	7953.91	2	37.84*
Factor "method"	8.88	2	0.44	204.15	3	0.65
"Plot" x "method"	563.40	4	13.89*	2106.85	6	3.34*
Residual	9044.07	891	-	49182.49	468	-
Total	10568.17	899	-	59410.52	479	-

was called the random cross method.

IV. Results and discussion

The mean yields (Table 1) seem quite different at first, but it is impossible to say by subjective evaluation of the data which of the methods overestimate or underestimate the yield. A two-factor analysis of variance was therefore employed:

$$x = \mu + P + M + PM + e$$

where x — resulting parameter, i.e. yield, μ — general effect of the experiment, P — effect of the factor "plot", M — effect of the factor "method", PM — interaction of " plot x method", e — random error in the experiment. As the sizes of the subplots were unequal by some of the methods, two variants of the statistical analyses were used. Only the data obtained by Methods 2, 3 and 4 were included in the first variant of the variance analysis. Yield values for 100 randomly selected subplots were used in an orthogonal dispersion complex in each method. The data obtained by all four methods were processed in the second analysis of variance, those obtained by Methods 2, 3 and 4 being occasionally grouped by fours and summarized. 40 groups were used in each method, and 40 random values were also chosen from the data of Method 1.

The results of the two analyses (Table 2) are similar. The factor "method" does not have any appreciable influence on the results of the experiment, implying that all the methods compared give statistically similar results. The same thing was also confirmed by detailed analysis of the individual levels of every factor, in that no level of the factor "method" had a high probability (Paal & Paal 1989). At the same time, the influence of the factor "plot" on the yield is evident, as was assumed empirically. Detailed analysis of the interaction "plot x method" showed that the third method underestimated the yield in the first plot, but overestimated that in the second plot. This may be caused be unequal variation in yield values when estimating them by different methods.

A very important question of preferring one method over another is their practicality. How much work and time do they take to achieve results at the required statistical level? From the point of laying out small subplots in nature, the wandering quarter method and the random cross method should be favoured. Both make it fairly easy to obtain a representative sample of the yield data. The nearest neighbour method needs additional work, and the most complicated of all is the first method of laying out the subplots, although we used blocks of quadrats rather than single quadrats. The preparing and transport of the wooden sticks and the measuring and marking of the subplots is rather time-consuming and laborious, and picking the berries is also tedious, as the subplots are four times larger than in the other methods, where the 0.5x0.5 m subplots are used and a simple frame is sufficient.

Table 3. Number of subplots required for estimating cowberry yields with 10% accuracy by the four methods.

Plot	Method			
	I	II	III	IV
1	55	126	146	89
2	206	250	373	207
3	123	226	170	125

A serious criterion when estimating the economy of a method is the number of subplots necessary to obtain data of sufficient accuracy. If we ignore the most laborious Method 1, the smallest number of subplots for 10% accuracy is needed by the random cross method (Table 3).

V. Conclusions

1. The comparison of four methods of laying out subplots for estimating cowberry yields — based on random coordinates, the nearest neighbour method, the wandering quadrats method and the random cross method — indicates that they give statistically the same results.
2. The most laborious and time-consuming method is the random coordinate method, and the most economical the random cross method.

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