Removal of Intervarietal Competetion Effects in Forestry Varietal Trials

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Abstract

The effects of intervarietal competition were modelled by using the average effects from neighbouring plots as a covariate. The coefficient for this effect was found to be effectively independent of a Papadakis coefficient. This model yields reduced varietal effects compared to the effects from a randomised block analysis.

It is recommended that in the analysis of varietal trials, field variation should first be eliminated by blocks and covariates, and then the intervarietal competition effects removed. A Papadakis term may also be included.

Key words: Varietal trials, competition, trends, Papadakis, row plots.

Zusammenfassung

Die Effekte der Zwischensortenkonkurrenz wurden mit Hilfe der Durchschnittseffekte der benachbarten Parzellen als Kovariable in einem Modell dargestellt. Es stellte sich heraus, daß der Koeffizient für diesen Effekt unabhängig war vom Papadakis Koeffizient. Dieses Modell bringt reduzierte Sorteneffekte, verglichen mit den Effekten von einem randomisierten Blockversuch.

Es wird empfohlen, daß in der Analyse von Sortenversuchen die im Feld gefundene Variation zunächst durch Blockbildung und durch Kovariable eliminiert werden sollte. Danach verschwinden die Konkurrenzeffekte zwischen Sorten. Die Methode nach Papadakis kann ebenfalls mit eingeschlossen werden.

Introduction

It is common in forestry varietal trials to use rectangular plots, each containing about 10 trees. Often these plots are not buffered, so trees in one plot are competing with the two plots on either side, and to a lesser extent with the plots at each end. If single row plots of ten trees are used, the competition effects between the ends of the plots will be of sufficiently small size that they can be ignored.

The between varietal competition will have two effects. Firstly it will bias the effects of individual plots, and secondly it will inflate the error. This study sought to quantify the effect of interplot competition in a varietal trial of *Pinus radiata* D. Don, and to quantify the bias on the estimates of the varietal effects, and on the residual error.

The removal of competition effects in varietal trials was recently considered by Kempton and Howes (1981) and Kempton (1982), using a modification of the randomised block model

$$y_{ij} = b_i + \tau_{[ij]} + \varepsilon_{ij} \qquad (1)$$

where b_i are block effects, $\tau_{[ij]}$ are treatment effects of varieties (i.e. varietal effects) applied to the j^{th} plot of the i^{th} block and ε_{ij} are the errors. They suggested using the observed values of neighbouring plots as a covariate to correct for competition, i.e.

$$y_{ij} = b_i + \tau_{[ij]} + \varkappa \bar{y}_{Nij} + \varepsilon_{ij} \qquad (2)$$

where $\varkappa$ is the competition coefficient. The use of observed values in competition models has also been used by Besag (1974), Gates (1978) and McMurtrie (1981). In general, the observed value of a plot in a varietal trial may be written as

$$y_{ij} = b_i + \tau_{[ij]} + \varkappa\, f(\mathfrak{x}, \mathfrak{e}) + \xi_{ij} + \eta_{ij}$$

$$\left[\text{where } \xi_{ij} + \eta_{ij}\right]$$

represent the local trend and plot components of the error ε_{ij}.

If the competition term of the model is taken as the mean of the observed neighbouring plots, i.e.

$$f(\mathfrak{x}, \mathfrak{e}) = \bar{y}_{Nij},$$

this term will be a function of treatment effects, local trend and plot error. $\varkappa$ will only be negative if competition dominates over local trend. If local trend dominates, $\varkappa$ will be positive, as is normally obtained by a Papadakis term. When estimating the effects of competition, we require a covariate that will not be dominated by local trend. Furthermore, we consider that the effects of competition may not necessarily be as strong in strong blocks as weak blocks. For example, since trees in deep soil are able to extract more nutrients, these will compete less with each other than trees on shallower soils. Accordingly we chose to use the varietal effects of the neighbouring plots as our covariate to remove intervarietal competition. After the block and varietal effects have been removed from an observed value, there remains the possibility of using this residual for detrending adjacent plots.

Experimental

The data used in this paper were measures of *P. radiata* D. Don obtained from Australian Progeny Trial 5411 grown in the south east of South Australia. At the time of measurement the trees had an average height of 10.8 m and a diameter at breast height of 120 mm. The experiment was arranged in ten blocks, each consisting of three plots. A different fertilizer treatment was applied to each plot. Within each plot were 30 varieties, each grouped into a single row of 10 trees. The main plots were surrounded by a guard row, but there was no separation between varieties. Further details of this trial are given by Cotterill *et al.* (in press). The present study considers the data as a randomized block trial of 30 replicates of 30 varieties.

Removal of Intervarietal Competition Component

The primary interest in this paper is with between varietal competition. Within varietal competition will not affect estimates of varietal effects since these will average out. Because each main plot is surrounded by a buffer row, intervarietal competion will only occur between the row plots. The buffers were not measured, so there exists no information on the size of the tree at either end of both the main plots and subplots. As a result, varieties at the ends of the main plots have only one neighbour contributing to intervarietal competition. Thus at the boundaries, we use this neighbour rather than the mean of two.

The mathematical model involving competition for a plot yield y suggested by DRAPER and GUTTMAN (1980) was

$$y_{ij} = b_i + \tau_{[ij]} + \kappa\, \bar{\tau}_{[Nij]} + \varepsilon_{ij} \qquad (3)$$

using the mean of the neighbouring treatment effects,

$$\bar{\tau}_{[Nij]}, \quad \text{for } f(x, \varepsilon).$$

The $\tau_{[Nij]}$ were estimated from a randomised block analysis and then used as a covariate in an analysis of covariance. This gave an improved estimate of the varietal effects, τ, and an estimate of $\varkappa$. Analyses of Covariance, using a covariate derived from the improved estimates of varietal effects, were repeated iteratively until stable estimates of $\varkappa$ and the varietal effects were obtained. In our analysis the value for $\varkappa$ converged to -0.441 with a standard error of 0.0978 (see *Table 1*). The resultant varietal effects are shown in *Figure 1*.

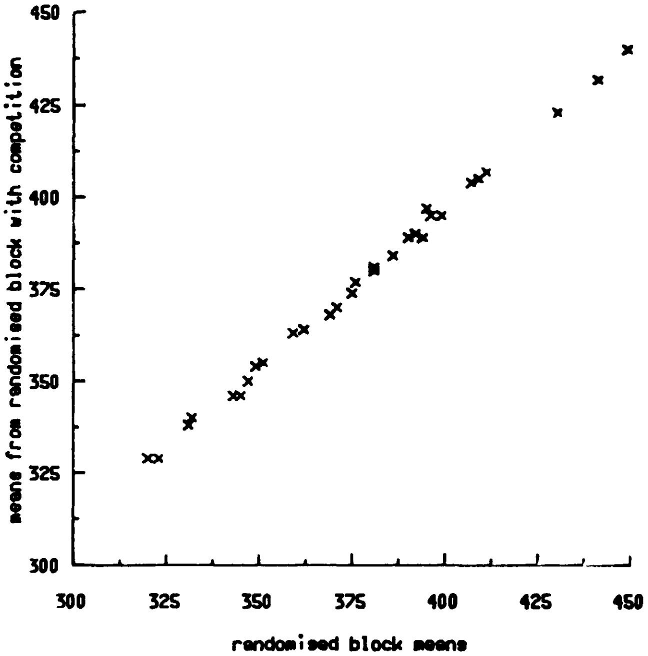

Figure 1. — Relation between effects obtained from a randomised block with competition compared to those from a randomised block analysis.

Removal of Trend by Papadakis Method

KEMPTON and HOWES, following BARTLETT (1978) also recommend the removal of trend by using the mean of residuals of neighbouring plots as a covariate. The Papadakis model with trend removal is

$$y_{ij} = b_i + \tau_{[ij]} + \beta\, \bar{\varepsilon}_{Nij} + \eta_{ij} \qquad (4)$$

where η_{ij} is estimated by $\beta\bar{\varepsilon}_{Nij}$ and β is the coefficient suggested by PAPADAKIS (1937) for the mean of the neighbouring residuals obtained from the first pass. In our case, only 1 iteration was used, so $\underset{\sim}{\varepsilon}$ are the residuals from a randomised block analysis. Iteration of this process was suggested by BARTLETT (1978), but this could lead to biased results (WILKINSON and MAYO (1982)). It is also our experience that iteration of this model does not always give numerically stable estimates.

The value we obtained for the Papadakis coefficient was 0.170 with a standard error of 0.0447. Because of the large number of residual degrees of freedom, the reduction in the residual mean square was less than 2% even though this coefficient is significantly greater than zero.

Combined Papadakis and competition model

After fitting varietal estimates corrected for competition a Papadakis covariate was included, the model being

$$y_{ij} = b_i + \tau_j + \kappa\, \bar{\tau}_{[Nij]} + \beta\bar{\varepsilon}_{Nij} + \eta_{ij} \qquad (5)$$

which can be estimated by the following algorithm

$$y_{ij} = b_i^{(n)} + \tau_j^{(n)} + \beta\, \bar{\varepsilon}_{Nij}^{(n-1)} + \kappa\, \bar{\tau}_{[Nij]}^{(n-1)} + \varepsilon_{ij}^{(n)}$$

$$\text{i.e. } \beta\, \bar{\varepsilon}_{Nij}$$

is only introduced into model (5) on the final iteration. The estimates obtained for $\varkappa$ and β were -0.445 and 0.182 respectively (see *Table 1*), representing effects due to competition and local trend. These estimates have a correlation of -0.014 signifying that they are effectively independent.

Table 1. — Summary of Analyses of Progeny Trial 5411.

Model No.	Analysis type	Treatment S.S. (10^{-05})	Residual S.S. (10^{-05})	Residual d.f.	Residual M.S. (10^{-03})	F for removal of trend w/in a block	F ratio obtained	Papadakis coeff	Competition coeff
1	Randomized block	9796	44790	841	5326		6.313		
2	Kempton & Howes Model	9946	44630	840	5313				
3	Randomized block with competition	6521	43730	840	5206		4.319		-0.441 ±0.0978
4	Randomized block with Papadakis	10370	44030	840	5242		6.920	0.170 ±0.0447	
5	Randomized block with competition and Papadakis	6560	42870	839	5110		4.428	0.182 ±0.0443	-0.445 ±0.0969
6	Randomized block with linear trends	9648	38840	811	4789	4.141	6.946		
7	Randomized block with linear trends and competition	8904	37640	810	4647	4.365	6.608		-0.54 ±0.102
8	Linear trends, competition & Papadakis	8899	37540	809	4640	3.829	6.613	-0.067 ±0.047	-0.540 ±0.102

Removal of linear trends within blocks

An assumption made in the classical analysis of a randomized block design is that the block effect is constant over the whole block. In this trial the blocks were over 60 metres in length and it is doubtful that soil fertility would remain even approximately constant over this distance. Accordingly we allow the fertility to have a gradient over the length of the block. This required fitting a separate parameter for each block, giving an estimate of the local trend ξ_{ij} as $t_i j$, where t_i is a linear trend within block i and j is the plot number within a block. The model is then

$$y_{ij} = b_i + t_i j + \tau_{[ij]} + \eta_{ij} \qquad (6)$$

The linear trends are not orthogonal to the varietal effects necessitating either inverting the design matrix or fitting constants iteratively. The fitting of constants is a relatively straightforward procedure as the parameters representing the trends within each block are independent. The algorithm we used for this procedure was

1. obtained treatment effects from a randomised block on $y^{(i)}$ form residuals $= y^{(1)}$ — fitted values
   ↓
   regress the plot number against the residuals for each block separately to obtain trends for each block
   ↓
   form $y^{(i)} = y^{(1)}$ — trend within the blocks
   ↓
   go to 1.

This algorithm converged rapidly and the treatment effects were stable to four figures after two iterations. The trends within blocks were very significant ($F_{30,811} = 4.14$) and their removal lowered the residual mean square by approximately 10% (see *Table 1).*

Removal of trends within blocks allowing for competition

Using the definition of intervarietal competition detailed above, an additional term gan be inncluded in model (6) giving

$$y_{ij} = b_i + t_i j + \tau_{[ij]} + \varkappa \bar{\tau}_{[Nij]} + \eta_{ij} \qquad (7)$$

As shown in *Table 1,* our estimate of $\varkappa$, representing competition, was -0.515 which is considerably higher than the previous estimates.

Removal of trends within blocks allowing for competition and a Papadakis coefficient

In model (7) we estimated the local trend η_{ij} by a linear trend within a block, whereas in model (5) the trend was estimated by $\beta\ \bar{\varepsilon}_{Nij}$. These two estimates can be combined by incorporating a Papadakis coefficient into model (6) to give

$$y_{ij} = b_i + t_i j + \tau_{[ij]} + \varkappa \bar{\tau}_{[Nij]} + \beta \bar{\varepsilon}_{Nij} + \eta_{ij} \qquad (8)$$

Table 1. shows that the coefficient of the Papadakis term was only 0.067 and had virtually no effect on the results compared to model (7). The coefficient was, however, effectively uncorrelated with the competition coefficient.

Discussion

Application of the intervarietal competition models (3), (5) and (7) in the analysis of this varietal trial considerably reduced the between treatment sum of squares, and the varietal effects were contracted to 0.87 of those from a randomised block analysis (see *Figure 1.).* This contraction of the varietal effects is consistent with the experience of Kempton (1982). Despite the large changes in treatment effects, there was little change in the ranking of the treatments. Use of these competition models will therefore be of more importance in the estimation of genetic gains rather than of varietal selection.

The simple competition model (3) has also been used in another *P. radiata* varietal trial (PT5031, described by Cotterill and Zed (1980)) and again resulted in a large contraction of varietal effects. Omission of invarietal competition may lead to exaggerated treatment effects.

The inclusion of a Papadakis term in models (4), (6) and (8) may remove a further competition component and/or local fertility trends. When added to the intervarietal competition model (4), it decreases the residual sum of squares rather than the between treatment sum of squares. The coefficient for the Papadakis term in our experience is effectively uncorrelated with the intervarietal competition term $\varkappa$. In an analysis of the sugar beet data given by Kempton (1982), estimates of these two components were -0.33 and -0.39 respectively, with a correlation of only -0.061. Fitting both these terms is equivalent to partitioning the Kempton and Howes model (2) into two effectively independent components. The use of the Kempton and Howes model in the 5411 data set was disappointing, as the coefficient was not significant. Separately both components were, however, very significant, but of opposite sign. It is recommended that in such analyses both components should be removed separately.

The Papadakis term in the model will reflect a mixture of competition and local trend. Where the local variation was reduced by removing a linear trend within each block, the coefficient of the Papadakis term changed from 0.182 to -0.065. Before fitting competition models, local fertility trends should be removed by blocking and using covariates as far as practical. Again, after fitting the trends within blocks, the varietal effects were still substantially the

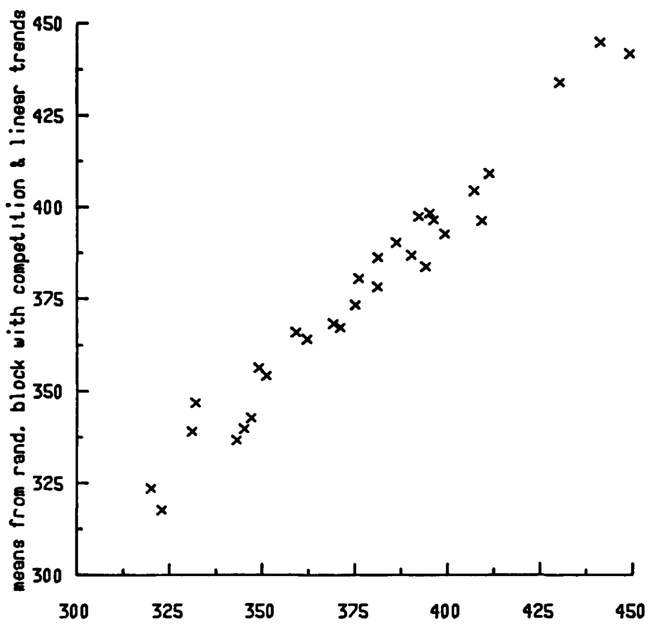

Figure 2. — Relation between effects from a randomised block after removing linear trends within blocks and competition, compared to randomised block effects.

same order as for the randomised block analysis (see *Figure 2.).*

The competition terms will correct the effects to the competition level of the trial mean, but when grown in a monoculture, the best varietes would produce a more competitive environment than that of the trial average and so will not perform as well as in the trial. KEMPTON suggested the treatment effects would be appropriate to that of the variety grown in a monoculture if the effects are divided by 1-$\varkappa$, where $\varkappa$ is the competition coefficient in our data, where $\varkappa = -0.54$, this is equivalent to multiplying the effects by 0.65. Ignoring this factor would give estimates of the effects that were much too large.

A further bias occurs when the best varieties are selected from a varietal trial. Those varieties that produce yields above their true potential are more likely to be selected than those performing poorly. This selection bias was discussed by PATTERSON and SILVEY (1980) and COTTERILL, CORRELL and BOARDMAN (1982). Unfortunately all three sources of bias from a randomised block trial tend to exaggerate the varietal effects.

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Variation of Eucalyptus camaldulensis from North Australia grown in Israel*)

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Summary

Variation of *E. camaldulensis* was studied in 71 families from 31 seed sources in North Australia. Clinal variation along latitudinal and longitudinal gradients occurs with regard to several of the characters investigated. Factor and cluster analyses with nine traits tend to group the seed sources according to major drainage divisions of North Australia: Timor Sea and Gulf of Carpentaria. Some provenances which occupy abnormal positions on the graphs are interpreted as Late Tertiary or Pleistocene relicts; the similarity between the Timor Sea and Gulf of Carpentaria provenances, on the one hand, and seed sources from the interior with drainage to inland lakes (Western Plateau, Lake Eyre), on the other, is apparently due to the disjunction of a formerly continuous distribution area as the result of climatic changes and/or modifications of drainage patterns.

In field trials, yields at 6 years of age ranged from 48.9 m^3 ha^{-1} to as little as 3.8 m^3 ha^{-1}. The Finke River, N. T., family 10489-J1235 is apparently from an elite tree with low provenance-site interaction. Considerable variation in yield between families from the same seed origin points to the possibility of significant genetic gains by selection of suitable seed trees of the most promising provenances. The importance is stressed of juvenile-mature correlations for early screening of high-yielding seed sources and families.

Key words: Eucalyptus camaldulensis, geographic variation, provenance trials, progeny tests.

Zusammenfassung

In Israel wurde die Variation von *Eucalyptus camaldulensis* bei 71 Familien aus 31 Herkünften aus Nordaustralien untersucht. Klinale Variation entlang von Breitengrad- und Längengradgradienten trat in Bezug auf einige der untersuchten Merkmale auf. Die Faktoren- und die Cluster-Analyse mit neun Merkmalen weisen auf eine Gruppierung der Herkünfte im Zusammenhang mit dem wesentlichen Einzugsbereich der zur See hin entwässernden Flüsse von Nordaustralien hin: Timor See und Golf von Carpentaria. Einige Provenienzen, die ungewöhnliche Positionen in den Graphiken besetzen, werden für spätterziäre oder pleistozäne Relikte gehalten. Die Verschiedenheit zwischen den Provenienzen vom Timor See und vom Golf von Carpentaria auf der einen Seite und den Herkünften aus den abflußlosen Gebieten des Landesinneren (Western Plateau, Lake Eyre) ist wahrscheinlich auf

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