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PROJECT REPORT No. OS27

INVESTIGATION INTO THE USE OF RESIDUAL MAXIMUM LIKELIHOOD (REML) FOR THE STATISTICAL ANALYSIS OF WINTER OILSEED RAPE VARIETY TRIALS

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INVESTIGATION INTO THE USE OF RESIDUAL MAXIMUM LIKELIHOOD (REML) FOR THE STATISTICAL ANALYSIS OF WINTER OILSEED RAPE VARIETY TRIALS

by

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Summary

In 1994 the Home Grown Cereals Authority commissioned a statistical review of the UK Recommended List winter oilseed rape trials programme. The final report of the review contained recommendations relating to the analysis of the data. The major of these recommendations was that the Residual Maximum Likelihood (REML) algorithm in Genstat should replace fitting constants as the preferred method for the statistical analysis of the major variates, and in particular for yield. However, problems were anticipated with the implementation of these recommendations and the routine use of REML.

This project addresses those problems and evaluates the effect that changing to REML has on variety performance ratings and statistical errors.

The problems associated with the application of REML to the Recommended List were overcome by the Statistics Department at IACR(Rothamsted) developing specific procedures to meet the Recommended List requirements. These procedures also enabled data to be analysed routinely.

The statistical analyses of the yield data showed that there is good agreement between the variety comparisons produced by fitting constants and REML but that the one-stage fitting constants severely underestimates error. REML should therefore, be used for future analysis for yield for which valid statistical errors are required.

The analyses of oil content showed that there is no advantage in using REML for this measure and fitting constants should continue to be used.

Extending the yield data to four years instead of three, improves the accuracy of the variety means for the established varieties. Therefore, future Recommended Lists should be based on four years' data.

It is proposed to adopt REML for the analysis of yield for the winter oilseed Recommended List and to extend the data set from three to four years. Fitting constants will continue to be used for the analysis of all other measures.

Postscript to the investigation.

The conclusions from the investigation were discussed with the relevant committees. Following these discussions, REML was implemented in autumn 1997 for the 1998 winter oilseed rape Recommended List.

1. Introduction.

In autumn 1994 the Home Grown Cereals Authority commissioned Professor Patterson and Mr B Church to carry out a statistical review of the UK Recommended List winter oilseed rape trials programme to check the accuracy and reliability of the system and to look for possible improvements. Their final report (Patterson and Church, 1995) contained recommendations relating to the analysis of the data. The major of these recommendations was that the Residual Maximum Likelihood (REML) algorithm should replace fitting constants as the preferred method for the statistical analysis of the major variates, and in particular for yield. The report acknowledged that initially there may be problems applying REML to the Recommended List routinely not only because of the large amount of memory and computing time needed to process a large data set, but also because the REML algorithm does not fully meet the Recommended List requirements.

The full recommendations are that :

i) fitting constants should be replaced by the Residual Maximum Likelihood (REML) algorithm recently added to Genstat and REML should be used for the routine analysis of major variates, with fitting constants being retained for purely descriptive variates.

ii) when available, four-year means should be used in preference to three-year means.

iii) routine statistical checks are needed for the effects of unusual seasons such as 1994.

iv) REML should also be used to calculate average components of variance over 8-10 recent years. These components are needed for (a) planning future series and (b) assessing the reliability of predictions based on results from the current series.

v) NIAB should also develop special procedures to (a) automatically identify groups of varieties whose relative performance differs between regions and (b) analyse responses to fungicide in paired trials.

Before REML could be implemented, it was necessary therefore, to address and resolve the problems associated with its use and to evaluate the effect that changing to REML would have on variety performance ratings and statistical errors. This document is a report of these investigations.

2. Background.

2.1 The UK Recommended List system.

The current variety testing system tests both new and established varieties in replicated performance trials at a number of sites throughout four regions in England, Wales and Scotland. The locations of the trials are chosen to reflect the distribution of the crop (Appendix 1). New varieties are tested at a subset of sites for two years before being considered for addition to the Recommended List. At the same time established varieties are tested not only at some of the same sites as the new varieties but also at a more extensive range of sites. Older varieties are removed from the system as they become superseded.

The majority of trials are treated with fungicide to control disease though at the later stages of testing, varieties are tested both treated and untreated at the same site. Yield, agronomic and quality records are taken, with data from the three most recent years' trials being combined and statistically analysed to produce variety means. Trials are also grouped by region to give variety means on a regional basis for treated yield. Results from these over year analyses form the basis of the UK Recommended List.

The very short period between harvesting the current season's crop and drilling the next, and the need to decide quickly which varieties are to continue in the trial system, mean that the over years analysis of yield needs to be constantly updated during harvest to include yield results as they are received. It is imperative therefore, that the processing system is able to carry out this updating quickly, easily and with minimum user intervention.

2.2 The data structure and methods of statistical analysis.

The structure of the trial system makes it is impracticable to grow new and established varieties in the same trials and in all years. Consequently, the varieties x trials tables for each year and the varieties x years tables are incomplete. An additional problem is that there are different numbers of trials in each year, and different numbers of trials in each of the four regions. These need to be taken into account in the analysis.

If the data set was complete, i.e. there was the same number of trials in each year, with all varieties being grown in all trials and in all years, the analysis would involve an orthogonal analysis of variance and the calculation of simple means. But this is not the case and therefore a more complicated statistical procedure has to be used. One such procedure is fitting constants (Yates, 1933).

A one-stage fitting constants method is currently used to analyse the Recommended List data (Patterson, 1978). In this analysis the data set is classified by varieties and trials. The analysis estimates comparable variety means adjusting for the non-occurrence of varieties in some trials. Equal weight is given to each trial with the effect that for example twelve trials in one year have the same weighting as four trials in three years. The one-stage fitting constants method has been applied to the Recommended List data sets for a wide range of crops for almost 20 years (Silvey, 1978).

An alternative approach to using a one-stage fitting constants analysis is to use a two stage analysis. This involves a fitting constants analysis being applied to each year's varieties x trials table, and then to the resulting table of varieties x years means. The choice between a one stage and a two stage analysis depends on the relative size of the different components of variance and the distribution of the number of trials between the years. A two stage approach has advantages when the year to year variation is greater than the between trial variation, but it has disadvantages in non-orthogonal data sets because it can distort results when a variety is grown in only a few trials in any one year.

Residual Maximum Likelihood (REML) may also be used (Patterson and Thompson, 1974). This differs from fitting constants in that it is suitable for analysing data from multi-way tables and therefore the classification structure of the data can be specified in more detail than with fitting constants. The analysis takes into account the different

levels of variation and interactions between the factors such as years, trials, varieties and regions when combining results to estimate variety means.

There is generally good agreement between the variety comparisons estimated by fitting constants and REML but it is recognised that the one-stage fitting constants method does severely underestimate errors.

REML is used for the analysis of incomplete block designs which have been used extensively for UK variety testing for many years. It is also used to estimate the components of variance required to measure the accuracy of various trial systems. It is a more complicated algorithm than fitting constants and as a result is more demanding on both computer memory and computer time. This has hampered its adoption as a method for routinely processing the large data sets associated with the Recommended Lists.

3. The investigation.

The investigation is divided into two parts. The first part concentrates on the identification and resolution of the problems associated with the application of REML to the Recommended List, and the development of a system to routinely process the data. The second part addresses the recommendations for data analysis and evaluates the effect that their implementation would have on the Recommended List results.

4. The application of REML to the Recommended List.

4.1 The statistical model.

Each data set used for the Recommended List can be classified by varieties, years, regions and trials. These classifying factors are used to define the statistical model used for the REML analysis. The choice of the model depends on the objective of the analysis. We are interested in estimating both variety means and variety x region means therefore, these are treated as fixed effects. All other effects are random and have components of variance estimated for them.

The statistical model relevant to the analysis is therefore :

$$V*R : Y + Y.R + V.Y + V.Y.R + Y.R.T$$

A colon separates the fixed and random effects, whilst varieties, years, regions and trials are represented by V, Y, R and T. The asterisk notation represents the combination of main effects and their interaction, i.e. V*R represents V + R + V.R. The dot notation is used to represent an interaction of two or more factors, e.g. V.R is the interaction of variety with region. This model is referred to in this paper as REML(A).

4.2 Problems with the analysis.

One of the major problems with running REML is its demand on computer time and memory. This demand is influenced by the size of the data, its incompleteness and the complexity of the statistical model used for the analysis. Initially there were problems fitting REML(A) but these were overcome by increasing the size of the PC. Even so some of the larger data sets, containing over 3000 items of data, still took over 30

minutes of processing time. For comparative purposes a one-stage fitting constants analysis of the same data set took approximately 2 minutes.

The time taken to process data was acceptable for this investigation but would cause concern when data are being analysed routinely to meet tight deadlines. Also, data sets for future Recommended Lists may be larger than those used in this investigation and hence are likely to require increased computer resources. This and the need to estimate long term components of variance will need to be borne in mind in the future.

Other problems relate to the negative components of variance that are sometimes estimated by REML. These negative components are dealt with by removing them from the model and reanalysing the data. This is currently carried out by user intervention.

There are also problems associated with estimating the variety means. The variety means estimated by REML(A) are derived from the variety x region means, giving equal weight to each region irrespective of the number of trials in the region. These variety means are not those required for the UK Recommended List because calculating them in this way defeats the objective of distributing trials to regions to correspond with the distribution of the crop. Various methods of weighting can be used, but for the List, the variety means are derived from the variety x region means weighted by the number of trials in each of the variety x region means.

REML(A) also has problems estimating variety means when a variety is not grown in a region. This situation is unlikely to arise when analysing treated yield data which is recorded on all trials. It may arise during the analysis of either oil content or untreated yields both of which are recorded only on a small number of trials. In such a case the validity of producing UK variety means should be questioned and an alternative method of analysis considered.

4.3 Amendments to Genstat.

The problems with the analysis were resolved by collaborating with the Statistics Department at IACR(Rothamsted) who developed procedures to take into account the specific Recommended List requirements and enable data to be processed routinely.

Two procedures were developed. The first one analyses the data using REML(A) subsequently, automatically omitting any negative components of variance from the model and rerunning the analysis. The processing time is minimised by specifying initial values for the variance components and by using an absorbing factor. The output from this analysis is saved for use by the second procedure. The second procedure retrieves the two-way table of variety x region means estimated by REML(A) and derives the variety means and standard errors allowing the user to either define the weighting factor or by default, to use the number of trials in each variety x region mean as weights. The default option is used for the Recommended List. This procedure also allows the users to ignore or include missing values when a variety has not been grown in a region.

These procedures have been used in the investigation.

5. The effect of the recommendations on the UK Recommended List results.

5.1 The effect of REML on treated yield.

5.1.1 Data and analyses.

Most analyses were carried out using treated yield data which is the major measure on the Recommended List(RL) but limited analyses were also carried out on oil content.

Data are currently stored on an Oracle data base and were abstracted into data files for input to Genstat. All analyses were carried out using Genstat 5 version 3.2 and a Pentium processor with a 16 megabyte hard disc.

The investigation used the three year data sets relating to the 1994, 1995 and 1996 Recommended Lists. Trials are grouped into four geographical regions, North (N), Central (C), South East (SE) and South West (SW). The varieties included in each analysis were those currently on the RL plus candidate varieties being considered for addition to the List. The numbers and distribution of trials in each of the data sets are shown in Table 1.

Table 1 : Numbers and distribution of trials

				Number of trials in each region			
	Years	Number of varieties	Total number of trials	N	C	SE	SW
RL 1994	1991-93	32	71	18	20	21	12
RL 1995	1992-94	17	74	17	17	26	14
RL 1996	1993-95	23	76	19	14	30	13

5.1.2 Results

Treated seed yield

The data sets were analysed using two-stage fitting constants (Fitcon 2) and REML(A) and the variety means compared with those already produced by the current method of analysis, one-stage fitting constants (Fitcon 1). The two-stage fitting constants method was used in the comparison because it is sometimes preferred to the one-stage method, and gives errors more similar to REML(A). The variety means estimated by the three methods and the differences from Fitcon 1 are presented in Appendices 2,3 and 4. A summary of the results are presented in Table 2. For ease of interpretation the yields in this table and in the appendices have been expressed as a percentage of the mean of the control varieties and to one decimal place because the majority of the differences are small.

The absolute differences from Fitcon 1 are generally small for the RL 1994 and RL 1995 data, with the largest difference being 1.4%. Differences are larger for the RL 1996 data set because there are greater varieties x years and varieties x regions interactions than in the previous sets. The large difference of 2.2% for Fitcon 2 relates to Cobra, a variety grown in only two trials in 1995. This shows the way in which a

great imbalance in the number of trials between years can distort a variety mean. Overall though, the variety comparisons from all three methods agree well.

Table 2 : Largest absolute differences from Fitcon 1 - treated seed yield - 3 years' data.

	Largest absolute difference from Fitcon 1 (as % mean of the controls)	
	Fitcon 2	REML(A)
RL 1994	1.4	1.0
RL 1995	0.9	1.0
RL 1996	2.2	3.4

The greatest difference between the results for the three methods is the change to the standard errors. It has always been recognised that a one-stage fitting constants severely underestimates errors and Table 3 shows the extent to which this occurs. As expected the standard errors from the two-stage fitting constants agree well with those from REML(A).

Table 3 : Average standard errors of differences - treated seed yield - 3 years' data.

	Average standard errors of differences between two variety means (as % mean of the controls)		
	Fitcon 1	Fitcon 2	REML(A)
RL 1994	1.65	2.31	2.32
RL 1995	1.63	2.95	3.16
RL 1996	1.73	3.29	3.28

5.1.3 Oil content

The RL 1995 and RL 1996 oil content data have also been analysed using REML(A) and the results compared with those from Fitcon 1. The results from the RL 1995 analysis are tabled in Appendix 5. Differences between the variety means for the two methods are extremely small, the largest absolute difference being 0.2% on means of the order of 40%. The change in the average standard error of differences is also small - 0.16 for Fitcon 1 compared with 0.27 for REML(A). The results for the RL 1996 comparisons (not tabled) show similar small differences.

5.2 Variety means for each region.

Several trial sites are situated very close to the boundary of one or more regions and currently, the results from these trials are used to derive the variety means for more than one region.

REML(A) cannot deal with this because the statistical model requires each site to be allocated to only one region. Therefore, the variety means for each region will be produced by carrying out a separate analysis on the data for each region. REML will be used for these individual region analyses.

5.3 The effect of using four years' data.

Basing the Recommended List on four years' data instead of three is logical for decision making. A variety is first considered for addition to the List in a provisionally recommended category after two years in trials. If added, it will continue in trials for two more years before being considered for full recommendation. At this stage the variety will have been in trials for four years. Currently, the Recommended Lists results are based on the most recent three years' data which means that when a variety is considered for promotion to full recommendation its first year's data is not used. This first year is likely to be a year in which a variety has performed well causing it to be selected as a Recommended List candidate. Using four years' data includes all available data for the variety up to the time when it is considered for promotion to the fully recommended category.

Intuitively, four years' data should provide a better estimate of variety means and should smooth out the effect an atypical year. Adding an earlier year's data to the data set will increase the amount of information for most of the established varieties giving a more precise estimate of their performance, a subsequent decrease in the standard error and hence an increase in the accuracy of the mean.

The effect of using four years' data has been evaluated by using the data sets for the 1994, 1995 and 1996 Recommended Lists treated yield. These data sets were extended to four years by including data from an earlier year and analysed using all three methods of analysis. The results from these analyses and the results from the equivalent three year analyses are tabled in Appendices 6,7 and 8. The increases in the number of trials resulting from using an extra year's data are also shown. For each Recommended List, the differences between the three and four year variety means from all three analyses are very similar, implying that the effect of adding an extra year's data is generally the same for all methods of analysis. As expected, the changes to the variety means for the varieties with no data in the earliest year are negligible. In all cases, extending the data to four years has reduced the standard error of the variety means and hence increased the confidence that we have in the means. The changes to the standard errors of differences are presented in Table 5.

Table 5 : Average standard errors of differences - treated seed yield - 3 years v 4 years.

	Average standard errors of differences between two variety means (as a % of the mean of the controls)					
	Fitcon 1		Fitcon 2		REML(A)	
	3 years	4 years	3 years	4 years	3 years	4 years
RL 1994	1.65	1.56	2.31	2.12	2.32	2.12
RL 1995	1.63	1.54	2.95	2.54	3.16	2.75
RL 1996	1.73	1.69	3.29	3.24	3.28	3.20

The individual effects of using REML(A) and four years' data have been evaluated in the above sections. The investigation of these effects is important but the changes that are of most concern are the changes to the variety comparisons resulting from using REML(A) and four years' data. These are shown in Appendices 9,10 and 11. Changes to the means for the Recommended varieties are generally small and are caused by a combination of the change in method and extra data. Most of these changes reflect differing variety performances in the earliest year. Changes to the variety means for the candidate varieties are small for the 1994 RL. The larger changes to the variety means for the candidates in RL 1995 and RL 1996 are caused by a change in the method of analysis and the way in which the larger varieties x years and the varieties x regions interactions have influenced the estimation of the variety means. These changes have affected the relative order of varieties.

5.4 Checks for the effects of unusual seasons.

An important part of the statistical work carried out for the Recommended List is the monitoring of the results and the identification of atypical changes in the variety comparisons. Current monitoring includes the presentation of variety mean yields for each year to assist with the identification of varieties that may interact with year. Additionally, the yield results and standard errors, from the over years analyses for successive Lists are compared to highlight any changes in the relative performance of varieties and the precision of the estimates. These methods will continue to be used.

In addition the monitoring will be extended to use the components of variance from the REML analyses. The way in which this will be done is illustrated by reference to the varieties x year (V.Y) and residual (Y.V.T + plot error) components of variance estimated for the three and four year RL data sets. The V.Y component is a measure of how the relative performance of varieties differs from year to year. The addition of data from an atypical year, i.e. one in which the varieties perform relatively differently than in earlier years, will result in an increase in the value of the V.Y component. The size of the increase indicates how differently the varieties are performing. The residual component is a measure of the relative variety performance from trial to trial. The V.Y and residual components are tabled in Table 6. It is seen that the V.Y component of variance for the 1991-94 data is very much larger than that for the 1991-93 data. This

indicates that the varieties performed very differently in 1994 compared with their performance in the period 1991-93 and that therefore 1994 was an atypical year. A similar change occurs with the 1992-94 and 1992-95 data but the effect is not so great. By comparison, the V.Y components of variance for the 1991-93 and 1990-93 data sets are very similar, suggesting that in 1990 the relative performance of varieties was very similar to that in the period 1991-93.

The V.Y and residual components of variance are used to derive the standard error of differences (SED). Therefore changes in the SED will also reflect the inclusion of data from an atypical year.

Table 6 : Components of variance and average standard errors of differences - treated seed yield in t/ha.

		Components of variance (t/ha)		
	Years	V.Y	Residual	Average SED (t/ha)
RL 1994	1991-93	0.0038	0.0550	0.0856
	1990-93	0.0032	0.0533	0.0789
RL 1995	1992-94	0.0146	0.0622	0.1255
	1991-94	0.0118	0.0590	0.1064
RL 1996	1993-95	0.0160	0.0671	0.1324
	1992-95	0.0168	0.0657	0.1290

Comparison of the components of variance from successive Lists provides evidence of changes in the precision of the variety comparisons and helps to identify the source of the change. The ideal way to identify any change in the components is by comparison with the long term components of variance derived from a much longer period, say 8 - 10 years. However, changes in the trials protocol means that only the four most recent years' data are relevant to the current trials system and this is insufficient to produce long term estimates. This work will be carried out as soon as the data are available.

5.5 The analysis of the response to fungicide.

At the later stages in the testing system varieties are grown both treated with fungicide and untreated, at a limited number of sites. Currently the treated and untreated yield data are analysed separately using Fitcon 1 with the response to fungicide (treated - untreated) being derived from the variety means. No measure of variability is calculated for this response. The review recommended that in future the response to fungicide should be analysed as opposed to including treatment as a fixed factor and this recommendation will be followed. Analysing the data in this way reduces the standard error of the response as is shown in Table 7. The variety means from the Fitcon 1 and

REML analysis are almost identical. Lack of data meant that no comparison could be carried out on the RL 1994 data set.

Table 7 : Standard errors for the yield response to fungicide (treated - untreated yield).

		Standard error of response (% mean of untreated controls)	
	Years	Treatment as a factor	Analysis of the response
RL 1995	1992-94	5.29	5.13
RL 1996	1993-95	6.07	4.65

5.6 Identification of varieties that interact with region.

Variety treated yields for each region are presented on the Recommended List and scrutinised for evidence of variety x region interactions. The Patterson and Church review identified the need to "develop procedures to routinely identify groups of varieties whose performance differs between regions". Preliminary work has been done on this and will continue not only because of its importance to the interpretation of the regional means on the winter oilseed rape Recommended List but also for the interpretation of the regional yields presented on the Recommended Lists for other crops.

6. Conclusions.

The development work carried out by IACR (Rothamsted) as part of this investigation means that it is now feasible to use REML routinely for the Recommended List. However, further work needs to be done to streamline the retrieval of data from the Oracle database. This will be carried out at NIAB. The time taken to process a data set is still of concern but recent use of the amended version of the REML algorithm, which utilises sparse matrix methods, has shown a considerable reduction in the processing time.

The generally good agreement between the variety comparisons produced by fitting constants and REML and the changes in the errors found in the investigation, support the statement made in the review that "the fitting constants procedure provides generally reliable differences between variety means but badly underestimates error, giving a spurious indication of accuracy." It is therefore, agreed that REML should be used for the analysis of yield for which valid estimates of error are required.

The changes to the variety means and standard errors for oil content resulting from the REML analysis are negligible and therefore, this measure should continue to be analysed by fitting constants.

Extending the data set to cover four years does provide a more accurate assessment of the variety comparisons for the established varieties and is logical from a decision making point of view. Future Recommended Lists should therefore be based on four years' data.

Monitoring procedures will be extended to use the components of variance from the REML analysis. Long term components of variance, when available, will be used as a baseline for the comparisons. The effect of any unusual years on variety comparisons will be brought to the attention of the relevant committee so that the change can be taken into account when making decisions.

Work should continue on ways of automatically identifying groups of varieties that interact with region because this will " add value" to the interpretation of the results.

7. Implementation of REML

The conclusions will be discussed with the relevant groups to seek agreement that from autumn 1997 onwards :

i) REML should be used to analyse the yield data used for the Recommended List.

ii) the data set for the Recommended List should be extended to four years.

8. Postscript to the investigation.

The conclusions from the investigation have been discussed with the oilseeds committees of both the HGCA and the British Society of Plant Breeders (BSPB), and with the NIAB oilseeds trials advisory committee (OTAC). Following these discussions, REML was implemented in autumn 1997 for the 1998 Recommended List.

The precision of the variety yield comparisons for the 1998 Recommended List were presented to the NIAB oilseeds trials advisory committee prior to them deciding which varieties should be included on the 1998 List. It is seen from Table 8 that the standard errors for the 1998 RL comparisons are lower than those for all previous Recommended Lists when the latter are recalculated using four years' data. This indicates an increase in precision for the variety means and the increased confidence that we can have in the decisions on the varieties.

Table 8 : Average standard error of differences - treated yield.

		Average standard errors of differences (as a % of the mean of the controls)	
	Years	Fitcon 1	REML(A)
RL 1994	1990-93	1.56	2.12
RL 1995	1991-94	1.54	2.75
RL 1996	1992-95	1.69	3.20
RL 1997	1993-96	1.62	2.57
RL 1998	1994-97	1.43	2.01

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Acknowledgement is also made to Dr R Thompson, and Ms S Welham, Statistics Department IACR (Rothamsted) for collaboration and development work carried out to adapt REML to the Recommended List application.

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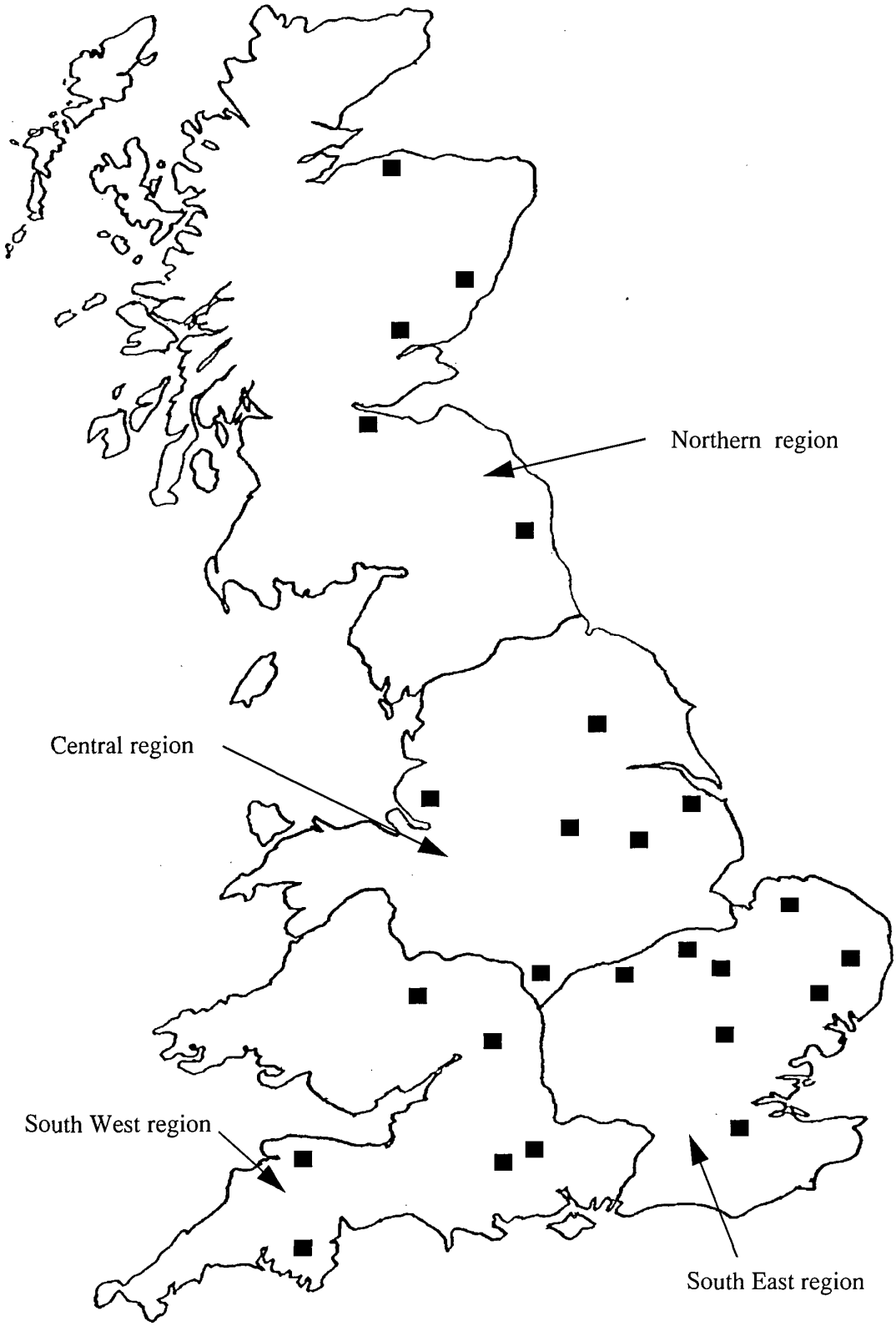
Appendix 1

Distribution of winter oilseed rape trials sites in the UK



Recommended List 1994

Treated seed yield in t/ha at 9% moisture as a % of the mean of the control varieties (c)

Data for 1991-93

				Difference from Fitcon 1			
	Fitcon 1	Fitcon 2	REML(A)	Fitcon 2	REML(A)	Number of trials	Number of years
Recommended varieties							
Cobra (c)	101.5	101.5	101.5	0.0	0.0	71	3
Falcon (c)	101.3	101.5	101.5	0.3	0.2	71	3
Libravo (c)	97.2	96.9	97.0	-0.3	-0.2	71	3
Envol	105.4	105.1	105.3	-0.3	0.0	54	3
Samourai	101.5	101.3	101.5	-0.3	0.0	54	3
Lictor	98.8	98.6	99.0	-0.3	0.1	36	2
Tapidor	95.3	95.0	95.2	-0.3	-0.1	53	2
Eurol	104.5	104.0	104.3	-0.6	-0.3	54	3
Idol	103.7	103.4	103.6	-0.3	-0.2	54	3
Rocket	101.0	100.5	100.9	-0.5	0.0	54	3
Bristol	110.0	109.7	109.8	-0.3	-0.2	54	3
Lineker	97.7	97.5	97.8	-0.3	0.0	54	3
Cobol	102.1	101.8	102.1	-0.3	0.0	53	3
Inca	105.9	105.9	106.1	0.0	0.2	45	3
Apache	101.8	101.5	101.8	-0.3	0.0	54	3
Apex	112.2	110.8	111.2	-1.4	-1.0	40	3
Mandarin	108.3	107.5	107.7	-0.8	-0.7	40	3
Gazelle	101.0	101.8	101.0	0.8	0.0	40	3
Express	103.2	103.7	103.0	0.5	-0.2	40	3
Alaska	104.8	105.1	104.5	0.3	-0.3	40	3
Candidate varieties							
Discovery	98.8	99.1	98.8	0.3	0.0	24	2
Lirago	99.9	100.2	99.8	0.3	-0.1	24	2
Zorro	100.7	101.0	100.4	0.3	-0.3	24	2
Symbol	104.5	104.5	104.2	0.0	-0.3	24	2
Tarok	103.7	104.3	103.6	0.5	-0.1	24	2
Astrol	102.4	102.6	102.1	0.3	-0.2	24	2
Lift	104.8	105.1	104.7	0.3	-0.1	24	2
John	101.0	101.5	100.9	0.5	-0.1	24	2
Commanche	102.9	103.2	102.6	0.3	-0.3	24	2
Chieftain	103.2	104.5	103.4	1.3	0.3	17	2
Celt	104.5	104.8	104.5	0.3	0.0	24	2
Ark	105.4	105.3	105.0	0.0	-0.3	24	2
Mean of controls (t/ha)	3.67	3.68	3.69				
Mean difference				0.0	-0.2		
se(difference)							
Average	1.65	2.31	2.32				
Maximum	2.15	2.58	2.84				
Minimum	1.13	2.09	1.86				

se - standard error

Recommended List 1995

Treated seed yield in t/ha at 9% moisture as a % of the mean of control varieties (c)

Data for 1992-94

				Difference from Fitcon 1			
	Fitcon 1	Fitcon 2	REML(A)	Fitcon 2	REML(A)	Number of trials	Number of years
Recommended varieties							
Apex (c)	105.6	105.7	105.3	0.1	-0.3	53	3
Bristol	103.3	103.2	102.7	-0.1	-0.6	54	3
Mandarin	101.3	101.4	100.9	0.1	-0.3	52	3
Inca	102.0	102.1	101.7	0.1	-0.3	45	3
Envol (c)	100.3	100.1	100.2	-0.1	0.0	63	3
Falcon (c)	100.0	100.4	100.5	0.4	0.5	74	3
Gazelle	99.7	99.4	99.1	-0.4	-0.6	52	3
Idol	98.7	98.6	98.3	-0.1	-0.5	54	3
Express	98.7	98.6	98.3	-0.1	-0.4	52	3
Rocket	96.9	96.8	96.6	-0.1	-0.4	54	3
Samourai	94.4	94.3	94.3	-0.1	-0.1	63	3
Libravo (c)	94.1	93.8	94.0	-0.3	-0.1	74	3
Candidate varieties							
Amber	104.6	103.9	105.5	-0.7	0.9	21	2
Nickel	106.1	105.2	106.8	-0.9	0.7	21	2
Hansen	103.1	102.4	104.1	-0.7	1.0	21	2
Tomahawk	100.8	100.4	101.8	-0.4	1.0	21	2
Commanche	100.0	99.4	99.2	-0.6	-0.8	42	3
Mean of controls (t/ha)	3.93	3.96	3.97				
Mean difference				-0.2	0.0		
se(difference)							
Average	1.63	2.95	3.16				
Maximum	2.18	3.41	3.70				
Minimum	1.16	2.78	2.72				

se - standard error

Recommended List 1996

Treated seed yield in t/ha at 9% moisture as a % of the mean of the control varieties (c)

Data for 1993-95

				Difference from Fitcon 1			
	Fitcon 1	Fitcon 2	REML(A)	Fitcon 2	REML(A)	Number of trials	Number of years
Recommended varieties							
Nickel	104.6	103.3	104.7	-1.2	0.2	40	3
Apex (c)	102.8	103.6	103.3	0.7	0.5	68	3
Amber	101.8	101.1	102.3	-0.7	0.5	40	3
Falcon (c)	101.8	101.6	101.8	-0.3	0.0	76	3
Gazelle	100.8	100.6	100.2	-0.2	-0.6	55	3
Bristol (c)	100.1	100.1	99.9	0.0	-0.2	59	3
Cobra	99.9	102.1	100.7	2.2	0.8	46	3
Inca	99.6	99.6	99.0	0.0	-0.6	55	3
Commanche	97.6	97.4	97.3	-0.2	-0.3	49	3
Envol (c)	97.6	97.6	97.9	0.0	0.3	76	3
Express (c)	97.6	97.1	97.0	-0.5	-0.6	58	3
Rocket	95.9	95.9	95.4	0.0	-0.5	55	3
Mandarin	95.4	95.2	94.8	-0.2	-0.6	55	3
Candidate varieties							
Synergy	113.2	114.9	115.4	1.7	2.1	26	2
Capitol	106.5	106.0	107.5	-0.5	1.0	25	2
Arietta	105.3	105.0	106.4	-0.3	1.1	25	2
Jazz	105.3	105.5	106.7	0.2	1.4	25	2
Lizard	105.1	106.3	108.4	1.2	3.4	24	2
Alpine	104.6	104.8	106.0	0.2	1.5	24	2
Corniche	104.3	104.3	105.6	0.0	1.3	25	2
Limpet	103.3	103.3	105.4	0.0	2.1	24	2
Limbo	102.3	102.3	103.7	0.0	1.4	25	2
Rapier	100.8	100.3	101.2	-0.5	0.4	32	3
Mean of controls (t/ha)	4.04	4.05	4.04				
Mean difference				0.1	0.6		
se(difference)							
Average	1.73	3.29	3.28				
Maximum	2.07	3.68	3.67				
Minimum	1.16	3.00	2.76				

se - standard error

Recommended List 1995

Oil content% - data from 1992-94

	Fitcon 1	REML(A)	Difference from Fitcon 1
Recommended varieties			
Apex	44.9	45.0	0.1
Bristol	44.7	44.7	0.0
Mandarin	42.4	42.4	0.0
Inca	44.1	44.1	0.0
Envol	44.7	44.7	0.0
Falcon	43.7	43.8	0.1
Gazelle	42.7	42.7	0.0
Idol	44.6	44.6	0.0
Express	45.6	45.6	0.0
Rocket	44.7	44.8	0.1
Samourai	44.4	44.2	-0.2
Libravo	44.0	44.0	0.0
Candidate varieties			
Amber	45.1	44.9	-0.2
Nickel	44.0	43.8	-0.2
Hansen	44.0	43.9	-0.1
Tomahawk	43.0	42.9	-0.1
Commanche	45.2	45.2	0.0
Mean	44.2	44.2	0.0
se(difference)			
Average	0.16	0.27	
Maximum	0.23	0.33	
Minimum	0.10	0.22	

se - standard error

Comparison of results from 3 years analysis (1991-93 data) and 4 years analysis (1990-93 data)

Treated seed yield in t/ha at 9% moisture as % mean of the control varieties (c)

	Fitcon 1			Fitcon 2			REML			Total number of trials		
	1991-93	1990-93	Difference from 1991-93	1991-93	1990-93	Difference from 1991-93	1991-93	1990-93	Difference from 1991-93	1991-93	1990-93	1990
Recommended varieties												
Cobra (c)	101.5	100.7	-0.8	101.5	100.9	-0.6	101.5	100.8	-0.8	71	99	28
Falcon (c)	101.3	101.3	0.0	101.5	101.4	-0.1	101.5	101.5	0.0	71	99	28
Libravo (c)	97.2	98.0	0.8	96.9	97.7	0.7	97.0	97.7	0.7	71	99	28
Envol	105.4	106.7	1.3	105.1	106.3	1.2	105.3	106.4	1.1	54	77	23
Samourai	101.5	101.8	0.3	101.3	101.4	0.2	101.5	101.7	0.2	54	77	23
Lictor	98.8	98.3	-0.5	98.6	98.2	-0.4	99.0	98.3	-0.7	36	64	28
Tapidor	95.3	95.6	0.3	95.0	95.2	0.2	95.2	95.4	0.2	53	81	28
Eurol	104.5	104.5	0.0	104.0	104.1	0.2	104.3	104.2	0.0	54	77	23
Idol	103.7	104.2	0.5	103.4	103.9	0.4	103.6	104.0	0.4	54	76	22
Rocket	101.0	101.3	0.3	100.5	100.9	0.4	100.9	101.1	0.1	54	77	23
Bristol	110.0	110.7	0.7	109.7	111.2	1.5	109.8	110.4	0.7	54	60	6
Lineker	97.7	98.6	0.8	97.5	98.7	1.3	97.8	98.4	0.6	54	60	6
Cobol	102.1	102.6	0.5	101.8	102.5	0.7	102.1	102.4	0.3	53	59	6
Inca	105.9	105.6	-0.3	105.9	104.9	-0.9	106.1	105.3	-0.7	45	51	6
Apache	101.8	102.3	0.5	101.5	102.2	0.7	101.8	102.0	0.2	54	60	6
Apex	112.2	112.3	0.2	110.8	111.2	0.4	111.2	111.3	0.1	40	40	0
Mandarin	108.3	108.6	0.2	107.5	107.9	0.4	107.7	107.8	0.1	40	40	0
Gazelle	101.0	101.3	0.3	101.8	102.0	0.2	101.0	101.1	0.1	40	40	0
Express	103.2	103.4	0.2	103.7	104.1	0.4	103.0	103.1	0.1	40	40	0
Alaska	104.8	105.0	0.2	105.1	105.2	0.1	104.5	104.6	0.1	40	40	0
Candidate varieties												
Discovery	98.8	99.1	0.3	99.1	99.6	0.5	98.8	99.0	0.2	24	24	0
Lirago	99.9	100.2	0.3	100.2	100.6	0.4	99.8	100.0	0.1	24	24	0
Zorro	100.7	101.0	0.3	101.0	101.4	0.4	100.4	100.5	0.1	24	24	0
Symbol	104.5	104.8	0.2	104.5	104.9	0.4	104.2	104.3	0.1	24	24	0
Tarok	103.7	104.0	0.2	104.3	104.7	0.4	103.6	103.7	0.1	24	24	0
Astrol	102.4	102.6	0.3	102.6	103.1	0.4	102.1	102.3	0.1	24	24	0
Lift	104.8	105.0	0.2	105.1	105.5	0.4	104.7	104.8	0.1	24	24	0
John	101.0	101.3	0.3	101.5	102.0	0.4	100.9	101.0	0.1	24	24	0
Commanche	102.9	103.2	0.2	103.2	103.6	0.4	102.6	102.8	0.1	24	24	0
Chieftain	103.2	103.4	0.2	104.5	104.9	0.4	103.4	103.5	0.1	17	17	0
Celt	104.5	104.8	0.2	104.8	105.2	0.4	104.5	104.6	0.1	24	24	0
Ark	105.4	105.6	0.2	105.3	105.8	0.4	105.0	105.1	0.1	24	24	0
Mean of controls (t/ha)	3.67	3.70		3.68	3.71		3.69	3.71				
Mean difference			0.0			0.0			0.0			
se(difference)												
Average	1.65	1.56		2.31	2.12		2.32	2.12				
Maximum	2.15	2.10		2.58	2.48		2.84	2.69				
Minimum	1.13	0.94		2.09	1.75		1.86	1.52				

se - standard error

Comparison of results from 3 years analysis (1992-94 data) and 4 years analysis (1991-94 data)

Treated seed yield in t/ha at 9% moisture as % mean of the control varieties (c)

	Fitcon 1			Fitcon 2			REML			Total number of trials		
	1992-94	1991-94	Difference from 1992-94	1992-94	1991-94	Difference from 1992-94	1992-94	1991-94	Difference from 1992-94	1992-94	1991-94	1991
Recommended varieties												
Apex (c)	105.6	105.7	0.1	105.7	105.5	-0.2	105.3	105.0	-0.2	53	59	6
Bristol	103.3	103.9	0.6	103.2	104.2	1.1	102.7	103.9	1.2	54	72	18
Mandarin	101.3	101.6	0.3	101.4	101.6	0.2	100.9	101.1	0.2	52	58	6
Inca	102.0	101.0	-1.0	102.1	101.6	-0.5	101.7	101.5	-0.2	45	63	18
Envol (c)	100.3	100.5	0.3	100.1	100.3	0.2	100.2	100.7	0.5	63	81	18
Falcon (c)	100.0	99.7	-0.3	100.4	100.3	-0.1	100.5	100.3	-0.2	74	98	24
Gazelle	99.7	100.0	0.3	99.4	100.1	0.7	99.1	99.5	0.4	52	58	6
Idol	98.7	98.7	0.0	98.6	98.8	0.2	98.3	98.7	0.4	54	72	18
Express	98.7	99.2	0.5	98.6	99.8	1.2	98.3	99.1	0.8	52	58	6
Rocket	96.9	97.4	0.4	96.8	97.5	0.6	96.6	97.5	0.9	54	72	18
Samourai	94.4	95.3	0.9	94.3	95.6	1.3	94.3	95.8	1.5	63	81	18
Libravo (c)	94.1	94.0	-0.1	93.8	93.8	0.0	94.0	94.0	0.0	74	98	24
Candidate varieties												
Amber	104.6	104.9	0.4	103.9	104.2	0.3	105.5	105.6	0.1	21	21	0
Nickel	106.1	106.5	0.4	105.2	105.5	0.3	106.8	106.9	0.1	21	21	0
Hansen	103.1	103.4	0.3	102.4	102.9	0.5	104.1	104.1	0.1	21	21	0
Tomahawk	100.8	100.8	0.0	100.4	100.6	0.2	101.8	101.8	0.0	21	21	0
Commanche	100.0	100.0	0.0	99.4	99.8	0.4	99.2	99.4	0.2	42	42	0
Mean of controls (t/ha)	3.93	3.84		3.96	3.85		3.97	3.87				
Mean difference			-0.1			-0.1			-0.1			
se(difference)												
Average	1.63	1.54		2.95	2.54		3.16	2.75				
Maximum	2.18	2.16		3.41	3.19		3.70	3.46				
Minimum	1.16	1.00		2.78	2.25		2.72	2.20				

se - standard error

Comparison of results from 3 years analysis (1993-95 data) and 4 years analysis (1992-95 data)

Treated seed yield in t/ha at 9% moisture as % mean of the control varieties (c)

	Fitcon 1			Fitcon 2			REML			Total number of trials		
	1993-95	1992-95	Difference from 1993-95	1993-95	1992-95	Difference from 1993-95	1993-95	1992-95	Difference from 1993-95	1993-95	1992-95	1992
Recommended varieties												
Nickel	104.6	104.5	-0.1	103.3	103.2	-0.1	104.7	104.8	0.1	40	40	0
Apex (c)	102.8	103.2	0.4	103.6	103.7	0.2	103.3	103.7	0.4	68	84	16
Amber	101.8	101.7	-0.1	101.1	101.2	0.2	102.3	102.4	0.1	40	40	0
Falcon (c)	101.8	99.8	-2.1	101.6	99.5	-2.1	101.8	99.8	-2.1	76	105	29
Gazelle	100.8	99.8	-1.1	100.6	99.5	-1.1	100.2	99.3	-0.9	55	71	16
Bristol (c)	100.1	101.0	0.9	100.1	101.0	0.9	99.9	100.7	0.8	59	77	18
Cobra	99.9	98.3	-1.6	102.1	100.2	-1.8	100.7	99.2	-1.5	46	75	29
Inca	99.6	99.8	0.1	99.6	100.0	0.4	99.0	99.7	0.7	55	64	9
Commanche	97.6	98.5	0.9	97.4	97.8	0.4	97.3	97.9	0.6	49	60	11
Envol (c)	97.6	98.3	0.6	97.6	98.3	0.6	97.9	98.5	0.6	76	94	18
Express (c)	97.6	97.8	0.1	97.1	97.5	0.4	97.0	97.3	0.3	58	74	16
Rocket	95.9	95.5	-0.4	95.9	95.3	-0.6	95.4	95.1	-0.2	55	73	18
Mandarin	95.4	97.0	1.6	95.2	97.0	1.9	94.8	96.8	2.0	55	71	16
Candidate varieties												
Synergy	113.2	113.5	0.2	114.9	115.1	0.2	115.4	115.2	-0.2	26	26	0
Capitol	106.5	106.5	-0.1	106.0	106.2	0.2	107.5	107.3	-0.2	25	25	0
Arietta	105.3	105.2	-0.1	105.0	105.2	0.2	106.4	106.2	-0.2	25	25	0
Jazz	105.3	105.2	-0.1	105.5	105.5	-0.1	106.7	106.5	-0.2	25	25	0
Lizard	105.1	105.2	0.2	106.3	106.2	-0.1	108.4	108.0	-0.5	24	24	0
Alpine	104.6	104.5	-0.1	104.8	104.7	-0.1	106.0	105.8	-0.2	24	24	0
Corniche	104.3	104.2	-0.1	104.3	104.5	0.2	105.6	105.4	-0.2	25	25	0
Limpet	103.3	103.2	-0.1	103.3	103.2	-0.1	105.4	104.9	-0.5	24	24	0
Limbo	102.3	102.2	-0.1	102.3	102.2	-0.1	103.7	103.5	-0.2	25	25	0
Rapier	100.8	100.5	-0.3	100.3	100.2	-0.1	101.2	101.5	0.2	32	32	0
Mean of controls (t/ha)	4.04	4.01		4.05	4.03		4.04	4.03				
Mean difference			0.0			0.0			0.0			
se(difference)												
Average	1.73	1.69		3.29	3.24		3.28	3.20				
Maximum	2.07	2.09		3.68	3.80		3.67	3.76				
Minimum	1.16	1.04		3.00	2.69		2.76	2.47				

se - standard error

Recommended List 1994

Comparison of results from current analysis and proposed analysis

Treated seed yield in t/ha at 9% moisture as % mean of the control varieties (c)

	Current analysis	Proposed analysis	
	Fitcon 1	REML(A)	Difference (proposed - current)
	1991-93	1990-93	
Recommended varieties			
Cobra (c)	101.5	100.8	-0.8
Falcon (c)	101.3	101.5	0.2
Libravo (c)	97.2	97.7	0.5
Envol	105.4	106.4	1.0
Samourai	101.5	101.7	0.2
Lictor	98.8	98.3	-0.5
Tapidor	95.3	95.4	0.1
Eurol	104.5	104.2	-0.3
Idol	103.7	104.0	0.3
Rocket	101.0	101.1	0.1
Bristol	110.0	110.4	0.4
Lineker	97.7	98.4	0.6
Cobol	102.1	102.4	0.3
Inca	105.9	105.3	-0.6
Apache	101.8	102.0	0.2
Apex	112.2	111.3	-0.9
Mandarin	108.3	107.8	-0.5
Gazelle	101.0	101.1	0.1
Express	103.2	103.1	-0.1
Alaska	104.8	104.6	-0.2
Candidate varieties			
Discovery	98.8	99.0	0.2
Lirago	99.9	100.0	0.1
Zorro	100.7	100.5	-0.2
Symbol	104.5	104.3	-0.2
Tarok	103.7	103.7	0.0
Astrol	102.4	102.3	-0.1
Lift	104.8	104.8	0.0
John	101.0	101.0	0.0
Commanche	102.9	102.8	-0.1
Chieftain	103.2	103.5	0.4
Celt	104.5	104.6	0.1
Ark	105.4	105.1	-0.2
Mean of controls (t/ha)	3.67	3.71	
Mean difference			0.0
se(difference)			
Average	1.65	2.12	
Maximum	2.15	2.69	
Minimum	1.13	1.52	

se - standard error

Recommended List 1995

Comparison of results from current analysis and proposed analysis

Treated seed yield in t/ha at 9% moisture as % mean of the control varieties (c)

	Current analysis	Proposed analysis	
	Fitcon 1	REML(A)	Difference (proposed - current)
	1992-94	1991-94	
Recommended varieties			
Apex (c)	105.6	105.0	-0.6
Bristol	103.3	103.9	0.6
Mandarin	101.3	101.1	-0.2
Inca	102.0	101.5	-0.5
Envol (c)	100.3	100.7	0.4
Falcon (c)	100.0	100.3	0.3
Gazelle	99.7	99.5	-0.2
Idol	98.7	98.7	-0.1
Express	98.7	99.1	0.4
Rocket	96.9	97.5	0.5
Samourai	94.4	95.8	1.4
Libravo (c)	94.1	94.0	-0.2
Candidate varieties			
Amber	104.6	105.6	1.0
Nickel	106.1	106.9	0.8
Hansen	103.1	104.1	1.1
Tomahawk	100.8	101.8	1.1
Commanche	100.0	99.4	-0.6
Mean of controls (t/ha)	3.93	3.87	
Mean difference			0.3
se(difference)			
Average	1.63	2.75	
Maximum	2.18	3.46	
Minimum	1.16	2.20	

se - standard error

Recommended List 1996

Comparison of results from current analysis and proposed analysis

Treated seed yield in t/ha at 9% moisture as % mean of the control varieties (c)

	Current analysis	Proposed analysis	
	Fitcon 1	REML(A)	Difference (proposed - current)
	1993-95	1992-95	
Recommended varieties			
Nickel	104.6	104.8	0.3
Apex (c)	102.8	103.7	0.9
Amber	101.8	102.4	0.6
Falcon (c)	101.8	99.8	-2.1
Gazelle	100.8	99.3	-1.5
Bristol (c)	100.1	100.7	0.6
Cobra	99.9	99.2	-0.7
Inca	99.6	99.7	0.1
Commanche	97.6	97.9	0.2
Envol (c)	97.6	98.5	0.9
Express (c)	97.6	97.3	-0.3
Rocket	95.9	95.1	-0.8
Mandarin	95.4	96.8	1.4
Candidate varieties			
Synergy	113.2	115.2	2.0
Capitol	106.5	107.3	0.8
Arietta	105.3	106.2	0.9
Jazz	105.3	106.5	1.2
Lizard	105.1	108.0	2.9
Alpine	104.6	105.8	1.3
Corniche	104.3	105.4	1.1
Limpet	103.3	104.9	1.6
Limbo	102.3	103.5	1.2
Rapier	100.8	101.5	0.6
Mean of controls (t/ha)	4.04	4.03	
Mean difference			0.7
se(difference)			
Average	1.73	3.20	
Maximum	2.07	3.76	
Minimum	1.16	2.47	

se - standard error