FINAL PROJECT REPORT
Canola Agronomic Research Program (CARP)

The Annual Final Report should fully describe the work completed for the year and note the personnel involved. It should also note any deviations from the original plan and next and/or corrective steps as may be required if deviations are noted. The report should also provide an update on the status of the Project including forecasted date of completion. A complete statement of expenses should be included. In the event major changes are anticipated within the budget supporting notes along with a proposed budget should also be included. The report should also capture a complete summary of activity for the year.

Project Title: CARP Project No. 2011-08 - Advanced statistical analysis of strip-plot canola variety trial data and comparison to small-plot variety trial data

Research Team Information

Lead Researchers:		
Name	**Institution**	**Expertise Added**
Dr. Anita Brûlé-Babel	Dept. of Plant Science University of Manitoba	Many years as Professor of Pla Breeding and Genetics
Research Team Members		
Name	**Institution**	**Expertise Added**
Dr. Gary Crow	Dept. of Animal Science University of Manitoba	Many years as Professor of Animal Genetics and Breeding, and Biometrician (statistics); retired 2012
Lyle Friesen	Dept. of Plant Science University of Manitoba	Research Associate. Statistical analysis, particularly Mixed Model analysis of large crop variety datasets using the specialized statistical computer program, ASReml.

Project Start Date: April 1, 2011 **Project Completion Date:** September 30, 2014

Reporting Period: Final Project Report

CARP Project Number: 2011-08

Instructions: This Annual Report shall be completed and submitted on or about March 31st of each fiscal year that the agreement is in effect. The Lead Researcher of the project in question shall complete and submit the report on behalf of his/her complete research team.

This Report is a means by which to provide a detailed update on the status of the project and summarize project activities. Details may be general in nature unless major issues or changes arise (e.g., change of scientists, significant change or delay of activities) including impacts on budgets. Please note that financial reports of major impact on budgets.

The following template is provided to assist you in completing this task. Please forward the completed document electronically to your appropriate CCC contact.

1. Forecasted Date of Completion:

September 30, 2014

2. Status of Activity: (please check one)

_____ **Ahead of Schedule** _____ **On Schedule** _____**Behind Schedule** ___x__ **Completed**

3. Completed actions, deliverables and results; any major issues or variance between planned and actual activities.

Note: To facilitate clarity and avoid confusion with the term 'small-plot', 'strip-plot' will be referred to as 'strip trial' for the remainder of this report. Small-plot refers to individual plots (usually in a replicated trial) that generally are no larger than 20 square meters in size (2 m by 10 m). Strip trial (also termed 'Field Scale' in the Seed Manitoba publication) are 'plots' that are much larger in area, often consisting of one width of a commercial scale seeder running the length of a field (the strips generally are not replicated at an individual trial location).

This final strip trial project report is somewhat similar to the March 31, 2014 report previously submitted, with regard to the comparison of Canola Performance Trial (CPT) yield small-plot versus strip trial results. This is reasonable since the Mixed Model analysis detailed below includes the relevant and available canola yield data (i.e. three years of data, 2011-2013 CPT data). The CPT canola data collected during the 2014 growing season was not available in time for analysis and inclusion in this final report. Australian researchers working on Mixed

Model analysis of crop variety trial data have indicated that approximately five years of data seems to be optimum for analysis, provided that there is some 'connectivity' in the yearly data – that is, that varieties are not all unique in each year of testing, but rather that there is more than one year of testing for a number of varieties in the multi-year dataset.

Associated with this final report is a copy of the previously submitted report on a comparison of canola yield small-plot results to strip trial results (private Industry strip trial data). Also, a summary of a comparison of canola yield small-plot results to commercial field results (Manitoba Agricultural Services Corporation, MASC data) is included in this final report – although a comparison to MASC data was not part of the original CARP project proposal.

Dr. Rale Gjuric of Haplotech, who is co-ordinating the independent canola variety trials (Canola Performance Trial - CPT) on behalf of the Canola Council, sent the CPT field scale (strip trial) canola yield data to us at the end of November in each of the three years (2011-13). Note that all field scale CPT data were generated and submitted by industry representatives, and not by independent third parties. Prior to 2011, canola strip trial results were not published in a widely available publication such as Seed Manitoba.

Prior to analysis, in each year the CPT strip trial raw dataset was re-formatted for the statistical computer programs, SAS and ASReml. Also, variety and location names were checked for consistent and correct spelling, and the three years of data were combined into one input datafile. A Mixed Model analysis was conducted on the 2011-13 CPT strip trial yield data using the Mixed Model statistical computer software program ASReml, which has been designed/optimized to accommodate large datasets. The summary tables of the strip trial (and small-plot) Mixed Model analysis are appended to this report. At the time of initiation of these CARP projects, it may not have been fully appreciated that this 'Strip Trial' project is very comprehensive in that it essentially includes and encompasses the companion project on small-plot canola data analysis. That is, before a comparison can be made between strip trial and small-plot results, the small-plot data also must be subjected to Mixed Model analysis. This Strip Trial project report includes this comparison to small-plot Mixed Model results, which is why the small-plot results tables/columns are appended herein.

For some background/introductory information on Mixed Model analysis of crop variety trial data, refer to the associated report using industry private strip trial data, 'Advanced Statistical Analysis of Strip-plot Canola Variety Trial Data and Comparison to Small-plot Variety Trial Data (yield)'. Refer to the accompanying 'pdf' file for the full report (Filename: UM Canola Yld Small Plot versus Strip Report_Nov 2012.pdf).

Summary of 2011-13 CPT Strip Trial/Field Scale Mixed Model Results (refer to tables appended to this report)

1) For the strip trial dataset CPT 2011-13 (inclusive), arithmetic yield means 'by Year', 'by Province', and 'by Year-Zone' are presented in the appended Table 1. The year 2013 had the

highest yield, approximately 1.3 fold higher than Year 2012. For the 'by Province' means, Alberta had the highest yield, while BC had the lowest yield (this result is quite different from the small-plot results). Similar to the small-plot results, the Short Season Zone (SSZ) had the highest yield in both 2011 and 2012, while the Long Season Zone (LSZ) had the lowest yield in both 2011 and 2012, probably due to growing season weather in the LSZ which was quite hot and dry during canola flowering in both 2011 and 2012. In 2013, LSZ had the highest yields (by a small margin), while mid-season zone (MSZ) and SSZ yields were quite similar.

2) The table of 'Variance Components' (Table 2 appended), details the variability in canola strip trial yield associated with various factors/effects in the statistical model. The statistical model used in the analysis can be deduced by the listing of effects and interactions in the variance components table. The major effect 'Year', and the interactions of 'Zone by Location' and 'Year by Zone by Location' were the important effects and interactions in terms of percentage of total variance; that is, these are the important effects and interactions in explaining the observed variability in canola yield in this strip trial dataset. All other effects and interactions (not including error/'Variance'/'Residual') were relatively small in terms of their contribution to total variance. The sum of all effects and interactions which included 'Variety' (genotype) were not very important in terms of percentage of the total variance at 2.7% despite the fact that there are significant differences between genotypes. This relatively small contribution of genotype in explaining the variability in yield is similar to other crop variety datasets that we have analyzed using Mixed Model procedures, and is in agreement with the scientific literature. Note that the 'Zone by Variety' interaction is not an important variance component, which indicates that Variety rankings do not 'flip' significantly by Zone (even though actual average yields in kg/ha differ between Zones) – this is similar to the small-plot results. This indicates that presenting a summary of strip trial canola variety performance by Zone is not necessary from a statistical point of view (at least for the dataset of 2011-13 strip trial CPT). Note that 'Location' is completely nested within 'Zone'.

The variance component estimate for the three-way interaction 'Zone by Location by Variety' is not well-estimated, but is on the 'boundary' of the solution space (refer to the ASReml Users manual for more information on boundary estimates – the ASReml Users manual is available for no charge as a downloadable pdf file over the Internet). Other interactions in the statistical model involving the factor 'Variety' are inconsequential in terms of their variance component values – it is unlikely that this three-way interaction of 'Zone by Location by Variety' is important.

3) In the table summarizing variety/genotype performance (Table 4), for most of the varieties there is generally good correspondence between arithmetic mean values and BLUP (Best Linear Unbiased Predictor) estimates, except for those varieties with a very low number of observations or for those varieties that were tested only in one year. It is an inherent property of Mixed Model analysis and the underlying matrix mathematics and algorithms that as the number of observations (statistical 'n') increases, the BLUP value and arithmetic mean will converge. This is reflected in the 'Unbiased' term in the BLUP acronym. Multiplying the 'Overall Standard Error of Difference' by 2 (or 1.96 as per statistical t-table) provides an approximate least significant difference (LSD) value at the 0.05 level of significance to statistically separate varieties yield. In this case this LSD value is approximately 160 kg/ha,

and results in a large number of varieties being declared not statistically different from each other in terms of yield. For example, the top 23 varieties (in terms of yield) were not statistically different (out of a total of 32 varieties). These results are similar to what has been observed in other crops and trials.

To compare CPT 2011-13 small-plot variety yield rankings to CPT 2011-13 strip trial yield rankings it is necessary to express the variety yields as a percent of a designated Check variety (or percent of a median BLUP yield value – the median BLUP value essentially treats the entire dataset as a 'basket' of Checks). This percent of Check approach is necessary for comparison because the overall arithmetic average yield (and yield potential) is quite different between the two growing environments. In this case, the overall arithmetic average small-plot yield is 3553 kg/ha (Year average, see Table 1 appended), while the strip trial overall average Year yield is 2773 kg/ha. This is a difference of approximately 30%. A median Check value was used rather than 'average', as average can be influenced/skewed somewhat by one (or a few) extremely large or extremely small values in the dataset. Interestingly, similar to the small-plot results, the strip trial median BLUP yield value is close to the variety '73-75RR' BLUP yield value – this variety has been used as a Check (Seed Manitoba 2013, 2014).

Short discussion on the importance of statistically significant differences between varieties' yields

As mentioned in point No. 3 above, it can be difficult to show statistical significance between variety yield estimates (BLUP's). However, an argument can be made that non-statistically significant differences between varieties are still important. If a large number of varieties are not significantly different from each other (for yield), then there should be little or no cost to choosing one variety over another (i.e. the cost of a Type 1 statistical error in this situation is minimal). For example, if Variety A has a 5% mean/BLUP yield advantage over Variety B, but this is not statistically significant, it still may be worthwhile to plant Variety A on the chance that it may outperform Variety B.

Probability Stability Analysis can be used to assign probabilities to Variety A outperforming Variety B (**Piepho, H.-P. and van Eeuwijk, F. A. 2002.** Stability analysis in crop performance evaluation. Pages 315-351 *in* M. Kang, ed. Crop Improvement: Challenges in the Twenty-first Century. Haworth Press, New York). Probability Stability Analysis combines mean and variance of a variety in an unambiguous way, but since the variance among varieties (yield) generally doesn't vary greatly (the authors have confirmed this with Spring Wheat variety yield datasets, and this is indicated by the Variance Component values), this calculation simplifies to essentially a comparison of variety yield means/BLUP's. The variance doesn't vary greatly between varieties because of yield stability – yields of registered varieties are quite stable across a wide range of environments as a result of the registration process, which selects for varietal yield stability.

An example of probability analysis (probability of Variety A outyielding Variety B), can be demonstrated using Manitoba Agriculture Seed Interactive with head-to-head comparisons for Spring Wheat (a summary of the presentation/example currently is available online at http://umanitoba.ca/faculties/afs/agronomists_conf/media/Brule-Babel_Pres_Dec_13_2012.pdf

This procedure might be able to be extended to using Manitoba Agricultural Services Corporation (MASC/Crop Insurance) data (and to crops other than Spring Wheat). If in the Central region using the MASC data, there were 100 farmers who grew 'Variety A' and 100 farmers who grew 'Variety B', then you would have 100 head-to-head comparisons (with, of course, some differences in management and localized weather). If 'Variety A' outyielded 'Variety B' in 75 out of 100 comparisons, then you would have a probability of 'Variety A' outyielding 'Variety B' in the Central region. If you increase the observation number (individual farmer reports to MASC) to a large number, then the 'noise' of differences in management and localized weather become less important. Mixed Model analysis also 'removes' or adjusts for the overall effect of year (growing season weather that influences yield). Therefore, for the above reasons, statistical significance of BLUP values is NOT the only consideration in comparison/selection of varieties.

Of course, when choosing a variety, the farmer should also consider other varietal agronomic characteristics and disease susceptibility, as well as yield.

Comparison of CPT 2011-13 Small-Plot and Strip Trial Mixed Model Analysis Results (refer to tables appended to this report)

1) There were more varieties tested in the small-plot trials versus the strip trials in the CPT 2011-13 dataset (Tables 3 and 4). The non-matching variety BLUP yield estimates from the small-plot trials were simply deleted from the comparison table (Table 4). There may have been some slight differences in small-plot variety BLUP estimates if the non-matching varieties had been deleted prior to running the Mixed Model analysis for this comparison, however, this was not done. Prior experience with Manitoba Crop Variety Evaluation Team (MCVET) datasets indicates that the exclusion of certain varieties (data subsets) prior to Mixed Model analysis does not greatly affect the remaining varietal BLUP yield estimates. The inconsequential variance components value for Variety/genotype and all interactions with Variety are confirmation of this (Table 2). Furthermore, in comparing small-plot and strip trial results and rankings, the reality is that the small-plot dataset was generated with the complete set of varieties.

2) Variety performance in small-plot versus strip trial (field scale) cannot be directly compared (using kg/ha values) because small-plot arithmetic average yields were higher than strip trial average yields by approximately 750 kg/ha in 2011, 370 kg/ha in 2012, and 1220 kg/ha in 2013 (Table 1). This yield advantage of CPT small-plot over strip trial (arithmetic average) for the three years of 2011, 2012, and 2013 is 1.26, 1.15, and 1.40 fold, respectively. These results suggest that the yield advantage (differential) of the small-plot growing environment over larger scale plots/trials is greatest in years with a very high yield potential (favourable weather).

In terms of actual crop yield (kg/ha), small-plot and commercial fields (or large scale trials) often differ, even when located in close proximity. Small-plot overall average yields are typically higher than larger field-scale average yields (pers. obs. and the above data/paragraph). This may occur because the high-cost, high-value, small-plot crop variety trials are generally situated on relatively uniform field sites with a high agricultural potential and are lavished with a high level of management and attention. Weeds and other yield-reducing pests are generally well-controlled or minimized in small-plot trials. Small-plot experiments are designed to provide comparative data on yield potential under as close to ideal conditions. It is rare that all parts of a commercial field would provide ideal growing conditions. Furthermore, past practice in western Canada has been that yield results from individual small-plot variety trials that do not meet a specified criteria (a cut-off Coefficient of Variation (CV) value) are immediately discarded and not added to the longterm database. Hi CVs are often associated with variable crop stands, uneven exposure to stress within the trial, and other management issues.

Therefore, as mentioned above, to compare small-plot versus strip trial variety performance and ranking, BLUP yield values for each variety were expressed as a percentage of a median BLUP yield value, with all varieties in the dataset included in the calculation of this median BLUP yield value (i.e. a 'basket' of check varieties which includes all varieties present in the dataset). Refer to Tables 3 and 4 for these percentage BLUP values.

Note that if a specific individual variety with a BLUP yield estimate close to the overall median BLUP value was chosen as the designated Check variety, results of this comparison would be similar. The designated Check variety in Seed Manitoba 2012, 2013, and 2014 was '73-75 RR'. The BLUP value for 73-75 RR in the small-plot results (Table 3) was close to the median BLUP value (differs by 1 kg/ha from the median BLUP value), while the BLUP value for 73-75 RR in the strip trial results was 25 kg/ha different from the median BLUP value (Table 4). Therefore it appears that 73-75 RR is fairly representative and appropriate as a designated Check variety (at least for the 2011-13 CPT small-plot and strip trial datasets). BLUP estimates for 73-75 RR were close to its arithmetic mean for both small-plot and strip trial datasets, and therefore likely are well-estimated.

3) There was greater variability in yield (kg/ha, arithmetic means) in the small-plot trials versus the larger scale strip trials. In the small-plot summary by 'Year' and 'Zone' (Table 1), the highest yield was for 2013 LSZ of 5429 kg/ha, while the lowest yield was for 2012 LSZ of 2317 kg/ha. This was a ratio of 5429/2317 = 2.3. In the strip trial summary by 'Year' and 'Zone' (Table 1), the highest yield was for 2013 LSZ of 3153 kg/ha, while the lowest yield was for 2012 LSZ of 2340 kg/ha. This was a ratio of 3153/2340 = 1.3.

4) Small-plot and strip trial variety BLUP values (% of median) are compared in Table 4. The comparison involved the Strip BLUP (%) subtracted from the Small-plot BLUP (%) for each matched variety. There are six out of 32 varieties where there were substantive differences (absolute value of 5% or larger) between Strip % BLUP yield and Small-plot % BLUP yield (Strip % minus Small-plot %). Three of these six discrepancies were positive in value (relative better performance in strip trial), and three of these instances were negative in value (relative better performance in small-plot). For five of the above six instances, the BLUP values were relatively close to their arithmetic means (both trial types), so the BLUP values likely were well-estimated (i.e. the differences between strip trial and small-plot performance were in fact real, and not likely due simply to chance). It is interesting that the three instances of substantive negative differences (relative better performance in small-plot) involve Liberty Link varieties (LL varieties often group near the top of the small-plot yield results, that is, they often yield very well in small-plot trials). The corresponding three instances of substantive positive differences (relative better performance in strip trial) involve two Roundup Ready varieties and one Clearfield variety.

This comparison indicates that correspondence between small-plot and strip trial (field scale) results was not as good as might be desired given the industry's reliance on small-plot testing in the early generations of canola genotype breeding and development. Reliance on small-plot testing is not likely to change due to economics, and the small amounts of seed available in the early generations of breeding and variety development.

In general, the results of the comparison of 2011-13 CPT small-plot to strip trial results were similar to our earlier reports on this subject. Therefore, the agreement between these studies was reassuring, and unfortunately it appeared that canola variety performance in small-plot trials was not always an accurate indication of how well a specific variety will perform in larger scale trials (or in farmers' commercial fields). The Manitoba Agricultural Services Corporation (MASC) commercial field yield data as published in 'Yield Manitoba' was analyzed and confirmed the above results (refer to the summary below in this final report). However, the MASC data tends to lag the initial commercial introduction of new varieties by several years as farmers adopt these new varieties. Also, there may be less confidence in the MASC yield estimates for some of the varieties with a low commercial acreage (i.e. variety matching with current small-plot results may be problematic).

Comparison of ASReml results to SAS PROC HPMIXED

ASReml is a joint Australian/British statistical computer program that was the first program developed that could accommodate Mixed Model analysis of relatively large datasets (i.e. 2000+ datalines), using some relatively new algorithms and matrix mathematics procedures developed in the 1980's - 1990's. SAS is a statistical computer program/system used extensively in North America (and less so internationally). Recent versions of SAS have included a Mixed Model analysis procedure that also is capable of analyzing large datasets (PROC HPMIXED).

For both the Small-plot and Strip trials, results of ASReml and SAS PROC HPMIXED were compared. In all instances, the variance component estimates were close between ASReml and SAS HPMIXED, but not identical. This is not surprising – Mixed Model analysis following the Restricted Maximum Likelihood (REML) algorithm is an iterative procedure - meaning that the results are a series of 'guesses' converging to a possible solution, and that when this series of 'guesses' is stopped (in SAS terminology "Convergence criterion (GCONV=1E-8) satisfied") influences the final values of the results. This is why almost all results of Mixed Model analysis are referred to as "Estimates". Furthermore, in all instances, the BLUP yield estimates and 'Overall Standard Error of the Difference' values were very similar between ASReml and SAS HPMIXED (differences were inconsequential).

Previous Mixed Model analysis of crop variety datasets (using ASReml) had raised a question as to whether nested effects in the statistical model were being evaluated correctly. Using SAS PROC HPMIXED (because of familiarity with specifying nested versus simple interaction effects in the statistical model), the statistical model was run twice – once with nested effects and once with simple interaction effects. In all the instances examined here, nested and non-nested specification resulted in an identical variance component estimate. This lack of difference between nesting and non-nesting specification has been observed in other unrelated analyses using SAS – it may be related to the underlying structure of the data. SAS has been under constant development, refinement, and constructive scholarly criticism for several decades with an active development team and user groups, therefore it is reasonable to assume that the matrix mathematics underlying the statistical analyses is being conducted correctly.

Comparison of Canola Small-plot to Strip Trial Results (yield) – Using Private Industry Data:

The following two paragraphs are a summary of the results of the investigation using Industry private strip trial data, 'Advanced Statistical Analysis of Strip-plot Canola Variety Trial Data and Comparison to Small-plot Variety Trial Data (yield)'. Refer to the accompanying 'pdf' file for the full report (Filename: UM Canola Yld Small Plot versus Strip Report_Nov 2012.pdf).

Every year in western Canada there is a large investment in testing of canola genotypes/varieties in both small-plot and larger scale trials ('strip trials'). A recurring question is: How well do the small-plot and strip trial results correspond with respect to ranking of variety performance (yield)? To investigate this question, a number of companies were invited to submit several years of recent canola strip trial yield data. This strip trial data was compared to small-plot data from a number of sources (refer to the body of this report for additional information on data sources). The small-plot and strip trial datasets were matched by variety prior to analysis; this resulted in relatively large datasets of 5,210 and 4,344 datalines, respectively. The variety-matched datasets were subjected to Mixed Model statistical analysis, and variety yield estimates (Best Linear Unbiased Predictor estimates, BLUP's) were compared.

For the datasets analyzed in this study, in terms of actual canola yield (kg/ha), small-plot trials had a greater yield than strip trials of approximately 1100 kg/ha (overall averages). This yield advantage of small-plot trials over larger-scale trials/commercial fields was in general agreement with long-standing observations for most crops that are evaluated under small-plot growing conditions. In terms of ranking the canola varieties for yield using a LSD test at the 0.05 level of significance, there was relatively poor agreement between the small-plot and strip trial results. The small-plot results identified many more significantly different varieties for yield than the strip trial results. That is, based on statistical significance, the small-plot BLUP variety yield estimates could be subset into groups of approximately 16 varieties (out of a total of 28), while the strip trial results had a large majority of the varieties declared not significantly different from each other (25 out of a total of 28). The reasons for this lack of agreement between canola small-plot and strip trial results were not evident in the datasets analyzed, however, it seems likely that strip trial growing conditions more closely resemble large-scale commercial field conditions than small-plot growing conditions.

Comparison of Canola Small-plot to MASC Results (yield)

The summary of a comparison of canola yield commercial field results (Manitoba Agricultural Services Corporation, MASC data as published in Yield Manitoba) versus small-plot results appears immediately below, while the complete report is appended.

Summary

Every year in western Canada there is a large investment in testing of canola genotypes/varieties in small-plot trials. A recurring question is: How well do the small-plot results correspond/predict variety performance in commercial fields? It can be argued that the Manitoba Agricultural Services Corporation (Crop Insurance) data as published in Yield Manitoba is the most accurate estimate of crop variety performance in commercial (farm) fields (for those varieties with a relatively high acreage – i.e. a relatively high sample number, statistical 'n'). For canola, a comparison of variety yield using Mixed Model analysis was conducted between the MASC data for 2008-2012 (inclusive) and the small-plot Prairie Canola Variety Trial (PCVT) 2003-2009 data and Canola Performance Trial (CPT) 2011-2012 data. There were no post-registration, third-party/independent, small-plot canola variety trials in the year 2010. Note that the commercial field/MASC data generally lags small-plot data by several years as new varieties are introduced and then subsequently adopted and widely grown by farmers. Because actual average (kg/ha) yields are greater in small-plot trials as compared to commercial fields, the results of Mixed Model analysis (Best Linear Unbiased Predictor estimates, BLUP yield values) for each variety were expressed as a percent of the variety '5440' for each dataset and then compared. The only overlap in varieties between PCVT 2003-09 and CPT 2011-12 small-plot datasets was 5440 (this probably is due to the relatively rapid turnover of canola varieties).

The intention of crop variety small-plot performance testing is to predict how the variety will perform in commercial fields. The correspondence between the MASC and the small-plot canola data (yield) was fair. After deleting varieties that were low acreage in the MASC dataset (a per variety total acreage cut-off for MASC of 20,000 acres prior to analysis), there were 47 canola varieties that matched between the MASC and small-plot datasets. Of these 47 canola varieties, the % BLUP values between the two datasets differed by 4.9% or more (absolute value) for 16 varieties when the MASC acreage cut-off was 20,000 acres (variety total acres grown over the five years in the MASC dataset). When the MASC acreage cut-off was 50,000 acres (total over five years), then there were nine varieties (out of 47) where % BLUP values between the two datasets differed by 4.9% or more (absolute value). Of these nine varieties with substantive differences, the difference was positive for six varieties (i.e. MASC % BLUP subtracted from small-plot % BLUP, that is, varietal performance in commercial fields was better than that predicted by small-plot results). Some of these 'large-difference' varieties seem to be important (based on MASC acreage), for example, the variety '8440' performed 6.7% better in commercial fields versus the small-plot result. Similarly, the variety '1012RR' performed 10.2% better in commercial fields versus small-plot. Conversely, the variety '5020' performed 5.1% worse in commercial fields versus small-plot. This is interesting because the variety '5020' was part of a designated small-plot check basket for a number of years, and hence has a large number of observations in the dataset (i.e. the small-plot BLUP estimate should be well-estimated). Also, '5020' was a widely grown variety with a large total acreage in the MASC dataset (again, the MASC BLUP estimate should be well-estimated). Both of the situations detailed above could potentially cost the farmer money; if farmers fail to adopt a better field-performing variety (because of small-plot results as published in Seed Manitoba) it will limit their potential returns. If farmers adopt and grow a poor field-performing variety based

on small-plot results (as published in Seed Manitoba), it obviously will limit their returns.

As mentioned, for six of the nine varieties with substantive differences, the difference was positive (i.e. MASC % BLUP subtract small-plot % BLUP, that is, varietal performance in commercial fields was better than that predicted by small-plot results The high-value, high-cost small-plot trials usually are located on relatively uniform field areas with a high agricultural potential and are lavished with high levels of crop inputs and management. Additionally, data from those small-plot trials that do not meet a current relatively stringent CV cut-off value are immediately discarded and not added to the longterm database (small-plot trials with a relatively high CV value may generally also be relatively low-yielding). Due to the larger year effect, we can expect differences between commercial yields and small-plot yield data as a result of the lag in commercialization of varieties from the time they were tested in small-plots. The main focus of small plots is to compare relative differences between varieties and provide an estimate of yield potential under ideal conditions. It should not be surprising that commercial yields differ from small plot yields.

It is notable that a relatively small number of canola varieties capture the vast majority of acreage of this crop grown in Manitoba. As stated above, the MASC dataset used in this analysis included 47 canola varieties (and there were many more low-acreage varieties listed in Yield Manitoba 2008-2012). Of these 47 varieties, only seven varieties had a total acreage of 500,000 acres or more over the five years of MASC data used in this analysis.

Overall Conclusions: Mixed Model analysis of canola small-plot and field-scale/strip trial data is appropriate and provides variety yield estimates that appear to be accurate. Currently, the results of CPT yield data analysis are presented as arithmetic means (in the 'Seed Manitoba' publication). Mathematical and statistical theory indicate that least-squares linear models (which is Mixed Model analysis) will always provide better or equal results to an arithmetic mean based approach. The advantage of Mixed Model analysis and adjusted 'means' (BLUP estimates) over arithmetic means becomes apparent where data is limiting and/or the year (growing season weather which influenced yield) was unusual as compared to a 10-year mean yield. Refer to Dr. Anita Brûlé-Babel's Manitoba Agronomists Conference presentation for a clear example of the superiority of Mixed Model analysis of crop variety trial data (using Spring Wheat as an example) http://umanitoba.ca/faculties/afs/agronomists_conf/media/Brule-Babel_Pres_Dec_13_2012.pdf

Based on the results of comparing canola yield small-plot results to larger scale growing environments (CPT strip trial, MASC commercial field), it appears that small-plot results are not a perfect predictor of variety performance under larger scale growing conditions. In both the CPT small-plot/strip trial and the small-plot/MASC commercial field comparisons, for approximately one-fifth of the varieties performance (yield) differed by 5% or more between the growing environments. This difference in performance may be related to growing conditions which are unique to small-plot trial environments in that the high-value, high-cost small-plot trials usually are located on relatively uniform field areas with a high agricultural potential and are lavished with high levels of crop inputs and management. Additionally, data from those small-plot trials that do not meet a current relatively stringent CV cut-off value are immediately discarded and not added to the longterm database (small-plot trials with a relatively high CV value may generally also be relatively low-yielding). If small-plot production/agronomic/growing conditions can be altered to more closely reflect actual commercial field conditions, then the predictive accuracy of small-plot variety testing might be improved. Small-plot testing of variety performance will continue to be important in crop variety breeding and development because seed stocks are limited in the early generations of variety development, and because of economics. Ultimately, the best assessment of variety performance is performance in commercial fields over a number of growing seasons (i.e. the MASC data).

4. Significant Progress/Accomplishments

See above (Section 3).

5. Research and Action Plans/Next Steps

The results of the Mixed Model analysis of the 2011-13 CPT strip trial yield data (and comparison to small-plot results) have already been sent to some key persons involved in the organization of canola small-plot variety trials and presentation of results. We welcome further consultation and discussion on this topic. When the 2014 CPT strip trial yield data becomes available (November, 2014), it can be merged with the 2011-13 CPT dataset (provided that there is some overlap in varieties tested) and an updated Mixed Model analysis conducted, along with comparison to small-plot results. Additional years of data in the Mixed Model analysis should lead to even more accurate variety BLUP yield estimates and variety rankings. The scientific literature suggests that five years of multi-location crop variety data in a Mixed Model analysis is desirable.

6. Budget impacts in the event major issues or variance between planned and actual is noted:

None anticipated.

Please forward an electronic copy of this completed document to:

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Table 1. Arithmetic summary of canola yield (kg/ha) for 2011-13 Canola Performance Trial (CPT) by Year, by Province, and by Year-Zone for: A. Small-Plot dataset. B. Strip Trial (Field Scale) dataset. (No. Obs. = number of observations, MIN = minimum, MAX = maximum, AVE = mean, STDev = standard deviation, STDerr = standard error, LSZ = long season zone, MSZ = mid season zone, SSZ = short season zone)

A. Small-plot dataset

			Yield (kg/ha)				
Year	Province /Zone	No. obs.	MIN	MAX	AVE	STDev	STDerr
2011		2096	1323	6851	3566	897.8	19.6
2012		1987	1023	5190	2782	745.5	16.7
2013		2096	1648	7162	4311	1006.5	22.0
			Overall average		3553		
	AB	2004	1601	6933	3789	958.0	21.4
	BC	560	1676	6851	4120	1129.1	47.7
	MB	712	1081	6509	3022	1145.0	42.9
	SK	2903	1023	7162	3439	1064.1	19.8
			Overall average		3593		
2011	LSZ	375	1822	4523	3283	582.4	30.1
2011	MSZ	965	1323	5387	3343	670.6	21.6
2011	SSZ	756	1636	6851	3990	1100.2	40.0
2012	LSZ	330	1081	3611	2317	573.7	31.6
2012	MSZ	1153	1023	5190	2810	828.1	24.4
2012	SSZ	504	1129	4248	3022	454.7	20.3
2013	LSZ	208	4028	7162	5429	580.5	40.2
2013	MSZ	1456	1648	6933	4068	1010.8	26.5
2013	SSZ	432	2946	6410	4589	658.4	31.7
			Overall average		3650		

B. Strip Trial dataset

Year	Province /Zone	No. obs.	MIN	MAX	AVE	STDev	STDerr
			Yield (kg/ha)				
2011		347	971	5030	2821	703.4	37.8
2012		529	797	4093	2410	560.6	24.4
2013		790	1701	4446	3089	523.1	18.6
			Overall average		2773		
	AB	696	943	5030	3111	617.9	23.4
	BC	12	2021	2919	2376	366.9	105.9
	MB	294	971	4138	2605	633.1	36.9
	SK	664	797	4446	2612	564.1	21.9
			Overall average		2676		
2011	LSZ	58	971	4806	2524	970.7	127.5
2011	MSZ	228	1229	5030	2845	644.1	42.7
2011	SSZ	61	2038	3980	3012	514.2	65.8
2012	LSZ	160	1011	4093	2340	591.8	46.8
2012	MSZ	273	797	3520	2385	486.1	29.4
2012	SSZ	96	943	3795	2598	661.9	67.6
2013	LSZ	130	1864	4435	3153	599.1	52.5
2013	MSZ	474	1701	4362	3082	506.6	23.3
2013	SSZ	186	2240	4446	3062	506.6	37.1
			Overall average		2778		

Table 2. Variance components for canola yield (kg/ha) for 2011-13 Canola Performance Trial (CPT) data determined using mixed model analysis with all effects and interactions specified as random for: A. Small-Plot dataset. B. Strip Trial (Field Scale) dataset. Syntax and terms follow the ASReml output.

A. Small-plot dataset

Source of Variation	Variance Component	Percentage of Total Variance
year	514702	37.6
zone	45643	3.3
variety	30834	2.2
zone.location	237167	17.3
year.location	374078	27.3
zone.variety	1769	0.1
year.variety	3776	0.3
year.location.rep	32359	2.4
location.variety	3634	0.3
year.location.variety	33673	2.5
error variance	92901	6.8

B. Strip Trial dataset[z]

Source of Variation	Variance Component	Percentage of Total Variation
year	96258	21.4
zone	5453	1.2
year.zone	8823	2.0
variety	6298	1.4
zone.variety	1725	0.4
year.variety	4170	0.9
zone.location	73775	16.4
year.zone.location	227673	50.5
zone.location.variety	0.0[y]	0.0
error variance	26679	5.9

[z] There were no replicates in the Strip Trial dataset.
[y] This estimate was very small (negligible) and was a result of the variance estimate being on the 'boundary' of the solution space (refer to the ASReml manual for further details). Additional terms and interactions could not be included in the statistical model due to resultant singularities in the Average Information matrix – this may be related to the structure of the dataset. For example, Location is completely nested within Zone, and furthermore, certain varieties may not have been tested in all zones.

Table 3. Summary of genotype/variety performance (yield) for the CPT Small-plot canola dataset 2011-13. Genotypes are presented in descending order based upon mixed model Best Linear Unbiased Predictor (BLUP) values.

			Yield (kg/ha)							
Genotype	Herbicide tolerance	No. obs.[z]	Minimum	Maximum	Arith. mean[y]	Traditional ANOVA STDerr	BLUP value	BLUP STDerr	Arith. mean – BLUP	BLUP (% of median BLUP)[x]
L252	LL	80	2277	7162	4821	133.1	4039	177.8	781	113.6
L261	LL	80	1648	6933	4537	135.4	3788	177.8	750	106.5
5440	LL	259	1127	6644	3749	72.3	3759	165.8	-10	105.7
L154	LL	168	1268	6509	3694	94.2	3752	169.2	-58	105.5
L150	LL	178	1128	6509	3415	79.1	3738	168.7	-323	105.1
L159	LL	168	1392	6526	3692	101.1	3729	169.2	-38	104.9
5770	LL	91	2024	6221	3809	98.1	3704	176.5	105	104.1
07H874	RR	90	2027	6128	3814	92.3	3701	176.5	113	104.1
1999	RR	66	1228	5062	2853	95.5	3689	179.2	-836	103.7
09H7757	RR	80	2148	6309	4432	107.7	3687	177.8	745	103.7
9571CL	CL	91	1967	6133	3750	98.8	3657	176.5	93	102.8
VR9559G	RR	179	1350	6449	3302	68.6	3652	168.6	-349	102.7
DL30509	RR	80	2168	6329	4386	112.5	3648	177.8	739	102.6
L130	LL	259	1211	6851	3621	71.6	3635	165.8	-14	102.2
8CN0024	LL	90	2171	6577	3735	90.4	3633	176.5	101	102.1
VT530G	RR	80	2085	6270	4351	112.3	3623	177.8	728	101.9
V12-1	RR	169	1081	6693	3566	89.5	3622	169.2	-56	101.8
CAN1990	RR	221	1259	6153	3530	70.3	3619	166.5	-89	101.7
VR9562GC	RR	80	2047	5940	4322	111.2	3601	177.8	722	101.2
74-47CR	RR	152	1181	6112	3638	88.5	3596	170.0	41	101.1
6060RR	RR	258	1190	6840	3578	70.1	3591	165.8	-13	101.0
CAN1970	RR	155	1114	6347	3260	86.2	3578	169.4	-318	100.6
SY4135	RR	80	2277	6710	4290	107.9	3575	177.8	715	100.5
73-75RR	RR	261	1348	6299	3535	60.1	3558	165.8	-23	100.0
VR9560CL	CL	169	1275	6056	3495	84.6	3555	169.2	-60	100.0
74-44BL	RR	168	1379	6412	3476	84.6	3548	169.2	-72	99.8

74-54RR	RR	80	1938	6176	4250	107.2	3538	177.8	712	99.5
VT520G	RR	88	1337	4568	2734	79.7	3514	176.6	-781	98.8
SY4114	RR	80	2089	6735	4222	105.5	3510	177.8	712	98.7
11DL30103	RR	80	2078	6709	4189	111.5	3491	177.8	698	98.1
73-55RR	RR	91	1647	6102	3530	82.8	3471	176.5	60	97.6
v1040	RR	90	1636	6272	3538	97.7	3469	176.5	70	97.5
L120	LL	88	1023	4357	2666	82.8	3450	176.5	-784	97.0
6050RR	RR	168	1126	6070	3369	83.4	3444	169.2	-75	96.8
72-65RR	RR	180	1265	6438	3093	63.8	3443	168.6	-351	96.8
DL30109	RR	80	2098	6015	4118	104.5	3415	177.8	703	96.0
73-45RR	RR	256	1284	6071	3382	58.3	3405	165.8	-24	95.7
5525CL	CL	257	1236	5869	3396	60.7	3405	165.8	-9	95.7
0CN0214	LL	90	1486	6096	3468	102.7	3403	176.5	65	95.7
V12-2	RR	80	2138	5877	4093	99.6	3401	177.8	692	95.6
94H04	RR	177	1102	5667	3028	65.5	3397	168.7	-369	95.5
CAN1980	RR	55	1593	4358	3130	79.1	3356	180.7	-226	94.4
1012	RR	53	1667	4025	3159	77.1	3351	180.9	-192	94.2
5535CL	CL	87	1285	3970	2543	68.1	3350	176.6	-807	94.2
VT510	RR	90	1544	5534	3390	88.0	3341	176.5	49	93.9
73-15RR	RR	114	1129	5359	3353	74.6	3265	171.1	88	91.8
Fusion	RR	90	1526	6063	3178	82.8	3153	176.5	25	88.6
2012	CL	53	1511	3872	2864	83.1	3138	180.9	-274	88.2

Overall standard error of difference[w] = 88.1

[z] Number of observations (rep values).
[y] Arithmetic mean.
[x] Percentage of a calculated median BLUP estimate, median of all genotypes (3557 kg/ha).
[w] An approximate LSD value at the 0.05 level of significance can be calculated by multiplying the Overall Standard Error of Difference by 2.0.

Table 4. Summary of genotype/variety performance (yield) for the CPT Strip Trial canola dataset 2011-13, and comparison to Small-plot CPT results (Table 3). Genotypes are presented in descending order based upon mixed model Best Linear Unbiased Predictor (BLUP) values.

			Yield (kg/ha)								
Genotype	Herbicide tolerance	No. obs.[z]	Minimum	Maximum	Arith. mean[y]	Traditional ANOVA STDerr	BLUP value	BLUP STDerr	Arith. mean – BLUP	BLUP (% of median BLUP)[x]	Strip BLUP (%) subtract Small-plot BLUP (%)[w]
L252	LL	42	2504	4222	3418	72.3	2832	84.0	586	104.1	-9.5
L130	LL	154	1213	5030	2977	54.0	2831	70.1	146	104.1	1.9
5440	LL	115	1258	4744	2962	65.9	2810	70.5	152	103.3	-2.4
L261	LL	40	2493	4250	3356	69.9	2803	84.1	553	103.0	-3.4
74-44_BL	RR	159	1196	4435	2910	48.5	2784	74.1	126	102.3	2.6
CAN1990	RR	75	994	4306	2702	75.6	2782	72.4	-80	102.3	0.5
L150	LL	101	797	4806	2673	70.6	2778	74.5	-105	102.1	-3.0
73-45RR	RR	185	943	4789	2815	47.8	2772	69.8	43	101.9	6.1
5770	LL	3	2897	4615	3602	519.1	2758	96.7	845	101.4	-2.8
74-54RR	RR	83	2083	4446	2984	51.7	2755	82.9	229	101.3	1.8
73-15RR	RR	68	1263	4396	2860	70.7	2753	73.6	107	101.2	9.4
73-75RR	RR	248	1027	4676	2788	38.1	2745	69.7	43	100.9	0.9
CAN1970	RR	17	1505	3599	2600	135.0	2735	82.9	-135	100.5	-0.1
L154	LL	50	1050	4053	2702	90.3	2734	76.4	-32	100.5	-5.0
1999	RR	8	1540	2637	2204	133.3	2727	91.4	-523	100.2	-3.5
VT530G	RR	1	2476	2476	2476	.	2723	103.8	-247	100.1	-1.8
SY4135	RR	6	2038	3526	3076	231.1	2718	92.1	359	99.9	-0.6
L159	LL	44	1072	4132	2640	104.1	2709	77.1	-68	99.6	-5.3
6050RR	RR	2	2942	3284	3113	171.2	2707	99.4	406	99.5	2.7
74-47_CR	RR	53	1594	4160	2750	72.9	2701	76.6	49	99.3	-1.8
SY4114	RR	6	2201	3542	3026	210.8	2693	92.1	333	99.0	0.3
CAN1980	RR	9	1976	3447	2780	164.7	2685	90.7	96	98.7	4.3
V12-1	RR	10	1875	3453	2863	160.4	2682	92.1	181	98.6	-3.2
94H04	RR	1	1740	1740	1740	.	2668	103.6	-928	98.1	2.6

6060RR	RR	44	887	4227	2446	86.3	2663	77.1	-216	97.9	-3.1
V12-2	RR	7	2302	3368	2944	151.1	2646	93.9	298	97.3	1.7
73-55RR	RR	1	1622	1622	1622	.	2645	103.6	-1022	97.2	-0.4
2012	CL	16	1151	3761	2408	159.9	2634	89.2	-226	96.8	8.6
L120	LL	11	825	2672	1974	182.3	2629	88.2	-655	96.6	-0.3
72-65RR	RR	66	1128	3756	2466	68.7	2611	76.1	-145	96.0	-0.8
v1040	RR	2	1555	2902	2229	673.7	2603	99.6	-375	95.7	-1.8
1012	RR	39	1465	3733	2554	88.4	2569	85.4	-16	94.4	0.2

Overall standard error of difference[v] = 78.5

[z] Number of observations.
[y] Arithmetic mean.
[x] Percentage of a calculated median BLUP estimate, median of all genotypes (2720 kg/ha).
[w] Strip Trial BLUP (%) subtract corresponding Small-plot BLUP (%) from Table 3.
[v] An approximate LSD value at the 0.05 level of significance can be calculated by multiplying the Overall Standard Error of Difference by 2.0.

MASC data versus Small-Plot comparison – Canola yield, November 2013
Lyle Friesen, University of Manitoba

[Note: The tabular summaries of all the small-plot analyses are not presented below in this report. The complete results of these analyses are available as an Excel workbook from the author, upon request.]

Summary: Every year in western Canada there is a large investment in testing of canola genotypes/varieties in small-plot trials. A recurring question is: How well do the small-plot results correspond/predict variety performance in commercial fields? It can be argued that the Manitoba Agricultural Services Corporation (Crop Insurance) data as published in Yield Manitoba is the most accurate estimate of crop variety performance in commercial (farm) fields (for those varieties with a relatively high acreage – i.e. a relatively high sample number, statistical 'n'). For canola, a comparison of variety yield using Mixed Model analysis was conducted between the MASC data for 2008-2012 (inclusive) and the small-plot Prairie Canola Variety Trial (PCVT) 2003-2009 data and Canola Performance Trial (CPT) 2011-2012 data. There were no post-registration, third-party/independent, small-plot canola variety trials in the year 2010. Note that the commercial field/MASC data generally lags small-plot data by several years as new varieties are introduced and then subsequently adopted and widely grown by farmers. Because actual average (kg/ha) yields are greater in small-plot trials as compared to commercial fields, the results of Mixed Model analysis (Best Linear Unbiased Predictor estimates, BLUP yield values) for each variety were expressed as a percent of the variety '5440' for each dataset and then compared. The only overlap in varieties between PCVT 2003-09 and CPT 2011-12 small-plot datasets is 5440 (this probably is due to the relatively rapid turnover of canola varieties).

The intention of crop variety small-plot performance testing is to predict how the variety will perform in commercial fields. The correspondence between the MASC and the small-plot canola data (yield) was fair. After deleting varieties that were low acreage in the MASC dataset (a per variety total acreage cut-off for MASC of 20,000 acres prior to analysis), there were 47 canola varieties that matched between the MASC and small-plot datasets. Of these 47 canola varieties, the % BLUP values between the two datasets differed by 4.9% or more (absolute value) for 16 varieties when the MASC acreage cut-off was 20,000 acres (variety total acres grown over the 5 years in the MASC dataset). When the MASC acreage cut-off was 50,000 acres (total over 5 years), then there were nine varieties (out of 47) where % BLUP values between the two datasets differed by 4.9% or more (absolute value). Of these nine varieties with substantive differences, the difference was positive for six varieties (i.e. MASC % BLUP subtract small-plot % BLUP, that is, varietal performance in commercial fields was better than that predicted by small-plot results). Some of these 'large-difference' varieties seem to be important (based on MASC acreage), for example, the variety '8440' performed 6.7% better in commercial fields versus the small-plot result. Similarly, the variety '1012RR' performed 10.2% better in commercial fields versus small-plot. Conversely, the variety '5020' performed 5.1% worse in commercial fields versus small-plot. This is interesting because the variety '5020' was part of a designated small-plot check basket for a number of years, and hence has a large number of observations in the dataset (i.e. the small-plot BLUP estimate should be well-estimated). Also, '5020' was a widely grown variety with a large total acreage in the MASC dataset (again, the MASC BLUP estimate should be well-estimated). Both of the situations detailed above could potentially cost the farmer money; if farmers fail to adopt a better field-performing variety (because of small-plot results as published in Seed Manitoba) it will limit their potential returns. If farmers adopt and grow a poor field-performing variety based on small-plot results (as published in Seed Manitoba), it obviously will limit their returns.

As mentioned, for six of the nine varieties with substantive differences, the difference was positive (i.e. MASC % BLUP subtract small-plot % BLUP, that is, varietal performance in commercial fields was better than that predicted by small-plot results). The high-value, high-cost small-plot trials usually are located on relatively uniform field areas with a high agricultural potential and are lavished with high levels of crop inputs and management. Additionally, data from those small-plot trials that do not meet a current relatively stringent CV cut-off value are immediately discarded and not added to the longterm database (small-plot trials with a relatively high CV value may generally also be relatively low-yielding). If small-plot production/agronomic/growing conditions can be altered to more closely reflect actual commercial field conditions, then the predictive accuracy of small-plot variety testing might be improved.

It is notable that a relatively small number of canola varieties capture the vast majority of acreage of this crop grown in Manitoba. As stated above, the MASC dataset used in this analysis includes 47 canola varieties (and there are many more low-acreage varieties listed in Yield Manitoba 2008-2012). Of these 47 varieties, only seven varieties had a total acreage of 500,000 acres or more over the five years of MASC data used in this analysis.

Datasets

MASC:

Data published in Yield Manitoba was the source of the MASC data. The MASC data for 2008 – 2012 (inclusive) was copied from online Yield Manitoba pdf's (archived at http://www.mmpp.com/mmpp.nsf/mmpp_publications.html). There are two consecutive years with acreages published in each Yield Manitoba issue. There are small revisions to the MASC data in the immediate following year, so it is more accurate to use 2-year old MASC data (however, this would preclude using the most recent MASC data and exacerbate the time lag between MASC and CPT small-plot data). These MASC data revisions may arise because of late submission of data. Generally these revisions to the MASC data are relatively minor (refer to a series of Yield Manitoba publications for examples for comparison) and are primarily related to acreage grown, and usually do not change the initial MASC yield estimate. Specifically for this analysis, MASC yield and acreage data for 2012 was copied from Yield Manitoba 2013, data for 2011 also was copied from Yield Manitoba 2013, data for 2010 was copied from Yield Manitoba 2012, data for 2009 was copied from Yield Manitoba 2011, and data for 2008 was copied from Yield Manitoba 2010. For the MASC dataset, those varieties with less than 20,000 acres in total (total over the 5 years) were deleted prior to Mixed Model analysis.

To calculate the approximate number of individual farms or farmers submitting MASC data (statistical 'n'), a number of assumptions can be made. Obviously, the larger the value of 'n', the more confidence can be placed in the accuracy of the MASC variety yield value. For example, given the following assumptions (these assumptions are conservative, i.e. they will provide a relatively low value for 'n'):

1) Average farm size of 2,000 acres (average farm size in Manitoba in 2011 was 1,135 acres according to Statistics Canada).

2) One-half of the farm planted to spring wheat and the other one-half planted to canola annually (i.e. 1,000 acres of each crop per year).

3) Only a single variety of each crop type planted on the 1,000 acres.

Then a MASC crop variety yield value where this variety has been grown on 20,000 acres in total would have been based on 20 individual farmer estimates (n = 20). These assumptions are obviously conservative with respect to calculating 'n', since farmers in Manitoba grow more crops than simply wheat and canola, and may grow more than one variety of each crop type on their farm in a given year.

PCVT and CPT:
The PCVT dataset used was the <u>entire</u> 2003-09 dataset with replicate values (approximately 35,000 datalines) as provided by the Canola Council of Canada. The CPT dataset used was the entire 2011-12 dataset with replicate values as provided by personnel involved with the CPT program.

Varieties in the MASC and small-plot datasets were NOT matched prior to analysis (but the post-analysis BLUP's were matched by variety). This procedure reflects reality – the trials occurred with the set of varieties that were tested in each year, and the results were published in Seed Manitoba, to which farmers look for guidance in variety selection. As mentioned above, the only overlap in varieties between PCVT 2003-09 and CPT 2011-12 small-plot datasets was '5440' (this probably is due to the relatively rapid turnover of canola varieties).

Results:
Note: Some of the following discussion is based upon results summarized/tabulated in a large, multi-worksheet Excel workbook which has NOT been appended to this report due to the difficulty of re-formatting many large (wide) Excel tables into MS-Word word-processor format. This Excel workbook is available from the author (Lyle Friesen) upon request.

The overall arithmetic average yield of the MASC canola dataset used in this analysis was 1,791 kg/ha. The influence of the relatively low-yield years (in Manitoba) of 2011 and 2012 is apparent.

The overall arithmetic average yield (averaged by Year) of the small-plot PCVT dataset used in this analysis was 3,084 kg/ha. The overall arithmetic average yield (averaged by Year) of the small-plot CPT dataset used in this analysis was 3,174 kg/ha. While the overall average yield is similar between the two small-plot datasets, it is quite different from the MASC (commercial field) overall average yield. This difference indicates that the MASC and small-plot datasets cannot be directly compared using actual kg/ha values, but that variety BLUP results must be expressed as a percentage of the common variety '5440' for each dataset (or possibly a person could use the median value of each dataset to calculate the percentage value for each variety). Using 5440 as the Check will minimize the effect of 'yield creep' over the years due to improved genetics, if this is present in the datasets (Year, or growing season weather that influenced yield, appears to have a large effect on canola yield – see the average yield summaries by year for each dataset in the appropriate Excel worksheet, available from the author upon request). Using a median value to calculate percentage values would not minimize the effect of yield creep. Presumably, the genotype 5440 is relatively stable in terms of genetic composition over the years.

The overall arithmetic mean yield for the canola strip-trial 2011-12 CPT dataset was 2615 kg/ha. This is further evidence that managed smaller acreage canola 'plots' generally have higher yields than commercial fields, and that yields in actual kg/ha cannot be directly compared between these growing environments. This difference in canola yield/yield potential between commercial fields (MASC) and strip-trial environments may influence the predictive accuracy of the strip-trial results in terms of ranking variety performance, similar to that observed for the comparison of MASC data to small-plot results – as described below.]

The range in MASC yield using 'by Year' averages was 2252/1416 kg/ha = 1.6. The range in small-plot yield using 'by Year' averages (and amalgamating PCVT and CPT by Year averages) was 3566/2660 kg/ha = 1.3 (refer to the Excel workbook, available from the author upon request). Therefore, the range in commercial field yields is greater than the range in small-plot yields – this may be due to the careful field location and management of small-plot trials. The greater range in commercial field yields could also reflect wider variation in crop management than would normally be seen with small plot trials.

The computer software program, ASReml was used for the Mixed Model analysis of each dataset. Variance components for each dataset are detailed in the spreadsheet tab labeled 'Variance Components' (refer to the Excel workbook, available from the author upon request). The variance components tables were similar to previous crop variety Mixed Model analyses results in that the factor/effect 'Variety' and the sum of all interactions which include 'Variety 'were not very important (as a percentage of total variance) in explaining the variability observed in yield. Important factors in the model were 'Year', 'Location', and the 'Year by Location' interaction.

For the MASC dataset, arithmetic means generally were close to BLUP values, particularly for those varieties with four or five observations (four or five years of MASC data) (refer to the table at the end of this report), which indicates that the Mixed Model analysis is occurring correctly. Based on Mixed Model matrix mathematics and algorithms, as the number of observations becomes large, the arithmetic mean and BLUP value will converge. This is reflected in the "Unbiased" term in the BLUP acronym.

Similarly, for the small-plot PCVT dataset, arithmetic means generally were close to BLUP values particularly for those varieties with a large number of observations (refer to the Excel workbook, available from the author upon request). Again, for the small-plot CPT dataset, arithmetic means generally were close to BLUP values particularly for those varieties that have a larger number of observations (i.e. varieties that were tested in both 2011 and 2012) – refer to the Excel workbook.

As mentioned, BLUP values were expressed as a percentage of '5440' BLUP for each dataset, and then these percentage values were compared (refer to the table at the end of this report).

Discussion regarding statistical significance of BLUP's (with regard to the trait, yield):
Multiply the 'Overall Standard Error of Difference' by 2.0 (or 1.96 as per statistical t-table) to calculate the approximate LSD value at the 0.05 level of significance (for the column of variety BLUP values for each dataset). Similar to other crop variety analyses, it can be difficult to show statistical significance between variety yield estimates (BLUP's), although there were some statistically significant differences between the varieties (all datasets). However, an argument could be made that non-statistically significant differences between varieties are still important. If a large number of varieties are not significantly different from each other (for yield), then there should be little or no cost to choosing one variety over another (i.e. the cost of a Type 1 statistical error in this situation is minimal). For example, if Variety A has a 5% mean/BLUP yield advantage over Variety B, but this is not statistically significant, it still may be worthwhile to plant Variety A on the chance that it may outperform Variety B.

Probability Stability Analysis can be used to assign probabilities to Variety A outperforming Variety B (**Piepho, H.-P. and van Eeuwijk, F. A. 2002.** Stability analysis in crop performance evaluation. Pages 315-351 *in* M. Kang, ed. Crop Improvement: Challenges in the Twenty-first Century. Haworth Press, New York). Probability Stability Analysis combines mean and variance of a variety in an unambiguous way, but since the variance of varieties (yield) generally doesn't vary greatly (LF has confirmed this with Spring Wheat, and this is indicated by the Variance Component values), this calculation simplifies to essentially a comparison of variety means/BLUP's. The variance doesn't vary greatly between varieties because of yield stability – yields of registered varieties are quite stable across a wide range of environments as a result of the registration process, which selects for varietal yield stability.

An example of probability analysis (probability of Variety A outyielding Variety B), is Brûlé-Babel's PowerPoint example of using Seed Interactive with head-to-head comparisons for Spring Wheat (a summary of her presentation currently is available online at http://umanitoba.ca/faculties/afs/agronomists_conf/media/Brule-Babel_Pres_Dec_13_2012.pdf This procedure might be able to be extended to using MASC data (and to crops other than Spring Wheat). If in the Central region using the MASC data, there were 100 farmers who grew 'Variety A' and 100 farmers who grew 'Variety B', then you would have 100 head-to-head comparisons (with, of course, some differences in management and localized weather). If 'Variety A' outyielded 'Variety B' in 75 out of 100 comparisons, then you would have a probability of 'Variety A' outyielding 'Variety B' in the Central region. If you increase the observation number (individual farmer reports to MASC) to a large number, then the 'noise' of differences in management and localized weather become less important. This is what is happening with Mixed Model analysis of the MASC data over five years (i.e. there are a large number of individual farmer reports for the large acreage varieties summarized in Yield Manitoba). Mixed Model analysis also 'removes'/minimizes the overall effect of year (growing season weather that influences yield). Therefore, for the above reasons, statistical significance of BLUP values is not the entire rationale in comparison of varieties.

Of course, when choosing a variety, the farmer should also consider other varietal agronomic characteristics and disease susceptibility, as well as yield.

[The following concluding paragraphs are the same as in the Summary above.]

It can be argued that the Manitoba Agricultural Services Corporation (Crop Insurance) data as published in Yield Manitoba is the most accurate estimate of crop variety performance in commercial (farm) fields (for those varieties with a relatively high acreage – i.e. a relatively high sample number, statistical 'n'). For canola, a comparison of variety yield using Mixed Model analysis was conducted between the MASC data for 2008-2012 (inclusive) and the small-plot Prairie Canola Variety Trial (PCVT) 2003-2009 data and Canola Performance Trial (CPT) 2011-2012 data. There were no post-registration, third-party/independent, small-plot canola variety trials in the year 2010. Note that the commercial field/MASC data generally lags small-plot data by several years as new varieties are introduced and then subsequently adopted and widely grown by farmers. Because actual average (kg/ha) yields were greater in small-plot trials as compared to commercial fields, the results of Mixed Model analysis (Best Linear Unbiased Predictor estimates, BLUP yield values) for each variety were expressed as a percent of the variety '5440' for each dataset and then compared. The only overlap in varieties between PCVT 2003-09 and CPT 2011-12 small-plot datasets is 5440 (this probably is due to the relatively rapid turnover of canola varieties).

The intention of crop variety small-plot performance testing is to predict how the variety will perform in commercial fields. The correspondence between the MASC and the small-plot canola data (yield) was fair (refer to the table at the end of this report). After deleting varieties that were low acreage in the MASC dataset (a per variety total acreage cut-off for MASC of 20,000 acres prior to analysis), there were 47 canola varieties that matched between the MASC and small-plot datasets. Of these 47 canola varieties, the % BLUP values between the two datasets differed by 4.9% or more (absolute value) for 16 varieties when the MASC acreage cut-off was 20,000 acres (variety total acres grown over the five years in the MASC dataset). When the MASC acreage cut-off was 50,000 acres (total over five years), then there were nine varieties (out of 47) where % BLUP values between the two datasets differed by 4.9% or more (absolute value). Of these nine varieties with substantive differences, the difference was positive for six varieties (i.e. MASC % BLUP subtract small-plot % BLUP, that is, varietal performance in commercial fields was better than that predicted by small-plot results). Some of these 'large-difference' varieties seem to be important (based on MASC acreage), for example, the variety '8440' performed 6.7% better in commercial fields versus the small-plot result. Similarly, the variety '1012RR' performed 10.2% better in commercial fields versus small-plot. Conversely, the variety '5020' performed 5.1% worse in commercial fields versus small-plot. This is interesting because the variety '5020' was part of a designated small-plot check basket for a number of years, and hence has a large number of observations in the dataset (i.e. the small-plot BLUP estimate should be well-estimated). Also, '5020' was a widely grown variety with a large total acreage in the MASC dataset (again, the MASC BLUP estimate should be well-estimated). Both of the situations detailed above could potentially cost the farmer money; if farmers fail to adopt a better field-performing variety (because of small-plot results as published in Seed Manitoba) it will limit their potential returns. If farmers adopt and grow a poor field-performing variety based on small-plot results (as published in Seed Manitoba), it obviously will limit their returns.

As mentioned, for six of the nine varieties with substantive differences, the difference was positive (i.e. MASC % BLUP subtract small-plot % BLUP, that is, varietal performance in commercial fields was better than that predicted by small-plot results). The high-value, high-cost small-plot trials usually are located on relatively uniform field areas with a high agricultural potential and are lavished with high levels of crop inputs and management. Additionally, data from those small-plot trials that do not meet a current relatively stringent CV cut-off value are immediately discarded and not added to the longterm database (small-plot trials with a relatively high CV value may generally also be relatively low-yielding). Due to the larger year effect, we can expect differences between commercial yields and small-plot yield data as a result of the lag in commercialization of varieties from the time they were tested in small-plots. The main focus of small plots is to compare relative differences between varieties and provide an estimate of yield potential under ideal conditions. It should not be surprising that commercial yields differ from small plot yields.

It is notable that a relatively small number of canola varieties capture the vast majority of acreage of this crop grown in Manitoba. As stated above, the MASC dataset used in this analysis includes 47 canola varieties (and there are many more low-acreage varieties listed in Yield Manitoba 2008-2012). Of these 47 varieties, only seven varieties had a total acreage of 500,000 acres or more over the five years of MASC data used in this analysis.

arison of canola variety performance (yield) in commercial fields (Manitoba Agricultural Services Corporation data, MASC) versus small-plot data
l analysis. The MASC data was obtained from data published annually in 'Yield Manitoba' (2008-12). The canola small-plot data was obtained fr
Test (PCVT) 2003-09, and Canola Performance Trial (CPT) 2011-12 datasets. With the exception of the variety '5440', there was no overlap in c
VT and CPT small-plot datasets – this may have been due to the rapid turnover of varieties and the omitted year of post-registration canola small
a in 2010. Refer to the text of this report (above) for additional information. Varieties are presented in decreasing order based on MASC BLUP yi

			Yield (kg/ha)												
	MASC Total acres[z]	MASC No. of obs. used in analysis (years)	MASC Min	MASC Max	MASC Arith mean[y]	MASC ANOVA STDev	MASC ASReml BLUP estimate[x]	MASC BLUP STD_Err	MASC Arith mean subtract BLUP estimate	MASC BLUP % of Median BLUP	MASC BLUP % of 5440 BLUP[w]	Small-Plot % 5440[v]	Small-Plot dataset source for % value	MASC % 5440 subtract Small-Plot % 5440	MASC % 5540 subtract Small-Plot % 5440 (diff is +/- 4.9% or greater AND acreage is >50,000 acres)
	825625	5	1684	2526	2100	394.2	2055	65.9	44	111.8	102.9	96.1	PCVT	6.7	6.7
	37988	1	1796	1796	1796		2016	117.0	-220	109.7	100.9	99.5	CPT	1.4	
	3593654	5	1516	2526	2032	472.0	1998	65.9	34	108.7	100.0	100.0	PCVT, CPT	0.0	
	257569	2	1684	1684	1684	0.0	1984	94.7	-300	107.9	99.3	89.1	CPT	10.2	10.2
	58311	2	2245	2695	2470	317.6	1969	94.6	501	107.1	98.5	88.1	PCVT	10.4	10.4
	26890	4	1403	2358	1909	520.6	1968	72.6	-59	107.0	98.5	--		--	
	20066	2	1572	1740	1656	119.1	1965	94.7	-309	106.9	98.3	--		--	
	125359	2	1628	1684	1656	39.7	1965	94.7	-309	106.9	98.3	95.3	CPT	3.0	
	1179737	2	1516	1796	1656	198.5	1965	94.7	-309	106.9	98.3	100.1	CPT	-1.8	
	582069	3	1516	2021	1722	265.3	1963	81.6	-241	106.7	98.2	98.9	CPT	-0.7	
	275497	5	1460	2414	1976	385.7	1951	65.9	25	106.1	97.6	95.9	PCVT	1.8	
	181221	3	1572	1853	1703	141.3	1948	81.6	-246	106.0	97.5	--		--	
	253666	3	1572	1909	1703	180.5	1948	81.6	-246	106.0	97.5	--		--	
	559086	2	1572	1684	1628	79.4	1946	94.7	-318	105.8	97.4	97.0	CPT	0.4	
	920100	5	1516	2526	1965	500.5	1941	65.9	23	105.6	97.1	96.6	PCVT	0.5	

21791	3	1403	1909	1684	257.2	1934	81.6	-250	105.2	96.8	86.4	PCVT	10.4	
44162	3	1516	1853	1665	171.5	1920	81.6	-254	104.4	96.1	92.5	CPT	3.5	
140757	3	1460	1909	1647	233.7	1905	81.6	-259	103.6	95.3	91.6	CPT	3.8	
26810	1	1572	1572	1572	.	1899	117.0	-327	103.3	95.0	96.0	CPT	-0.9	
194880	5	1403	2470	1909	494.2	1894	65.9	15	103.0	94.8	--		--	
43816	2	1460	1628	1544	119.1	1888	94.7	-344	102.7	94.5	--		--	
53493	2	1516	1572	1544	39.7	1888	94.7	-344	102.7	94.5	95.7	CPT	-1.3	
36880	2	1516	1572	1544	39.7	1888	94.7	-344	102.7	94.5	95.5	CPT	-1.0	
218679	5	1460	2302	1897	381.6	1884	65.9	13	102.5	94.3	90.5	PCVT	3.8	
89318	5	1572	2358	1897	353.7	1884	65.9	13	102.5	94.3	88.7	PCVT	5.6	5.6
399040	5	1460	2302	1886	390.1	1875	65.9	11	102.0	93.8	94.6	PCVT	-0.7	
23929	1	1516	1516	1516	.	1870	117.0	-354	101.7	93.6	--		--	
53515	3	1179	1853	1591	360.9	1862	81.6	-272	101.3	93.2	--		--	
87190	4	1460	2133	1768	280.7	1853	72.6	-85	100.8	92.7	--		--	
219912	5	1291	2414	1853	522.1	1847	65.9	6	100.4	92.4	90.3	PCVT	2.1	
41435	2	1853	2245	2049	277.9	1845	94.6	204	100.3	92.3	90.3	PCVT	2.0	
39148	1	1460	1460	1460	.	1840	117.0	-381	100.1	92.1	91.5	CPT	0.5	
223263	5	1235	2470	1841	563.3	1837	65.9	4	99.9	91.9	--		--	
103176	3	1516	2245	1965	393.0	1813	81.4	151	98.6	90.7	89.9	PCVT	0.8	
41970	2	1403	1460	1431	39.7	1811	94.7	-379	98.5	90.6	--		--	
115443	2	1403	1460	1431	39.7	1811	94.7	-379	98.5	90.6	--		--	
105213	5	1291	2358	1808	430.1	1809	65.9	-1	98.4	90.5	90.4	PCVT	0.1	
254201	4	1347	2302	1712	440.8	1808	72.6	-96	98.3	90.5	91.3	CPT	-0.9	
21269	3	1347	1628	1516	148.5	1805	81.6	-289	98.2	90.3	91.6	CPT	-1.2	
151461	2	1347	1460	1403	79.4	1792	94.7	-388	97.4	89.7	83.4	CPT	6.2	6.2
72207	1	2245	2245	2245	:	1787	116.9	458	97.2	89.4	94.4	PCVT	-4.9	-4.9
32971	1	2133	2133	2133	.	1784	117.0	349	97.0	89.3	84.9	PCVT	4.3	
797935	5	1067	2302	1774	512.4	1780	65.9	-6	96.8	89.1	94.2	PCVT	-5.1	-5.1
28532	4	1347	1965	1670	268.7	1773	72.6	-103	96.5	88.7	--		--	
445890	3	1572	2245	2002	373.8	1765	81.4	237	96.0	88.3	87.7	PCVT	0.7	
48002	3	1460	2189	1871	373.8	1742	81.4	130	94.7	87.2	88.4	PCVT	-1.2	

	56920	4	1235	2245	1628	432.4	1739	72.6	-111	94.6	87.0	88.1	PCVT	-1.1	
	34318	2	1235	1403	1319	119.1	1734	94.7	-415	94.3	86.8	--		--	
	34251	3	1067	1909	1422	436.0	1733	81.6	-311	94.3	86.7	92.4	CPT	-5.7	
	21872	1	2021	2021	2021	.	1725	117.0	296	93.8	86.3	75.6	PCVT	10.7	
	28657	3	1235	1572	1403	168.4	1719	81.6	-315	93.5	86.0	85.8	PCVT	0.2	
E	22053	3	1067	1684	1403	312.6	1719	81.6	-315	93.5	86.0	--		--	
	185003	5	1347	2245	1695	347.0	1714	65.9	-18	93.2	85.7	89.9	PCVT	-4.1	
	273152	2	2021	2133	2077	79.4	1699	94.6	378	92.4	85.0	--		--	
	93475	5	1067	2302	1673	505.9	1695	65.9	-22	92.2	84.8	--		--	
	135372	5	1291	2133	1650	417.5	1676	65.9	-25	91.1	83.8	84.5	PCVT	-0.7	
	100202	5	1067	2189	1628	443.8	1657	65.9	-29	90.1	82.9	77.9	PCVT	5.0	5.0
	73891	5	1067	2133	1617	431.9	1647	65.9	-30	89.6	82.4	80.7	PCVT	1.7	
	127520	5	786	2302	1572	649.8	1609	65.9	-37	87.5	80.5	85.6	PCVT	-5.1	-5.1
	45842	4	1010	2021	1460	420.1	1602	72.6	-143	87.1	80.2	84.6	PCVT	-4.4	
	49335	5	786	2077	1460	545.7	1514	65.9	-55	82.4	75.8	81.1	PCVT	-5.3	
	22584	3	1067	1909	1591	457.2	1449	81.4	141	78.8	72.5	89.3	PCVT	-16.8	
	32126	5	730	2133	1370	537.9	1438	65.9	-69	78.2	72.0	80.4	PCVT	-8.4	
	27743	5	842	1740	1246	455.0	1334	65.9	-88	72.5	66.7	74.3	PCVT	-7.5	

SED: Overall Standard Error of Difference[u] 118.6

ith less than 20,000 acres in total over the five years were deleted from the MASC dataset prior to analysis. MASC data from 'Yield Manitoba' were expressed as kg/ha prior

Unbiased Predictor).

nted as a percentage of the variety '5440' (the one variety that was common to all three datasets – MASC, PCVT, CPT) because overall average yields (yield potential) differ
nd small-plot environments, which precluded using actual kg/ha data for comparison (overall arithmetic averages were MASC 1791, PCVT 3084, CPT 3174 kg/ha). Refer to t
information.

small-plot analyses is not presented here – it is available as an Excel formatted workbook from the authors upon request.

SD value at the 0.05 level of significance can be calculated by multiplying the Overall Standard Error of Difference by 2.0.