Synopsis of selected SAS macros to be used for meta-analysis. Only the macro statement and the comments are given here (see the SAS program file to view the full code). Example in red is for the analysis of slopes given in Shah and Dillard. Instructions on the use of SGPLOT for creating a Forest plot is given at the end.

```
%MACRO meanes(es,w,dsn=_last_,print=raw) ;
*---Lipsey-Wilson macro for mean effect size and other statistics,
      based on MOMENT-type calculations. Macro made available for distribution courtesy of
      David Wilson. If you use, please cite book: Practical Meta-Analyis, by M. W. Lipsey
      & D. B. Wilson. 2001. Sage Publications, Thousand Oaks, USA.
      [Some macro additions by L. Madden];

…
```

Example: %***meanes***(slope,wgt,dsn=shah,print=raw) ;

```
%MACRO metareg(es,w,x,dsn=_last_,model=fe) ;
*---Revised Lipsey-Wilson macro, 7/2005 (L. Madden).
      This version CORRECTLY does the ML estimation (but maybe not REML). Macro made
      available for distribution courtesy of David Wilson.
      If you use, please cite book: Practical Meta-Analyis, by M. W. Lipsey & D. B. Wilson.
      2001. Sage Publications, Thousand Oaks, USA.;
*---Does moment (MM) or ML estimation.;

…
```

```
%MACRO metaf(es,w,x,dsn=_last_,model=fe) ;
*---Revised Lipsey-Wilson macro, 7/2005 (L. Madden).
      This version CORRECTLY does the ML estimation (but maybe not REML). Macro made
      available for distribution courtesy of David Wilson.
      If you use, please cite book: Practical Meta-Analyis, by M. W. Lipsey & D. B. Wilson.
      2001. Sage Publications, Thousand Oaks, USA.;
*---Does moment or ML estimation;

…
```

```
%macro moments(dfile=,es=,wgt=,study=);
*---Experimental macro, provided as-is (that is, provided with no warranty).;

*---Macro is an alternative to the 'meanes' macro by Wilson (see above).
      This uses SAS procedures and data steps to conduct a univariate MOMENT-based
      meta analysis, instead of an IML program. In some ways, the advantage of this
      macro is for educational purposes -- demonstrating how to obtain the needed
      statistics for the simple case of no moderators. Program also is useful
      for obtaining the I-squared heterogeneity index of Higgins and Thompson.;
*---Macro written by L. Madden.;

*---In general, I prefer likelihood-based meta-analyses, but many use the
      moment approach (thus, this macro).;

/*
dfile         name of the sas data file with data
es            name of variable in dfile with the effect size response variable
wgt           name of the weight variable in dfile. This needs to be the
```

```
               inverse of the "sampling variance" for each study
study          variable name for the labeled study (trial) in dfile

Macro creates various variables and data files starting with the underline symbol (_).
As a precaution, it is best if you do not have any variables or file names that
start with this symbol. Macro also overwrites titles starting at title2.

After running the macro, the data files _q_out2 and _q_out3, which contain the
results, are available for further processing (if needed).
*/
```

…

Example: ***%moments***(dfile=shah,es=slope,wgt=wgt,study=study);

```
%macro funnel(dfile=,es=,wgt=,study=,minprec=2,maxprec=80,numb=25);
*---Experimental macro, provided as-is (that is, provided with no warranty);

*---Macro produces a funnel graph and a radial plot for assessing whether or
       not a random study effect is needed. These diagnostics, especially the
       funnel graph, are very common in some disciplines (but not yet in plant
       pathology). Macro written by L. Madden.;

*---Funnel graph: plot of "precision" vs. effect size, with a vertical line
       for FIXED-effect common effect size, and curves for the confidence intervals
       around the common effect size. If "too many" points are outside the curves,
       this is evidence for a random effects analysis.
       In this application, precision is the inverse of the within-study SE;
*---Ideally, the funnel graph should be symmetrical. Gaps (say, on the lower
       left or right), can indicate PUBLICATION BIAS, where nonsignificant results
       are not published or made available. However, the gaps could be due to
       other factors, so this is just a guide. These graphs originiated with, or
       were advocated by, Light and Pillemer, Sterne et al., and Egger et al.;

*---Radial plots, also known as Galbraith plots, show the standardized effect
       size (_es_/SE) versus precision (1/SE) for each study. The slope of the line
       through these points is the FIXED-effects common effect size. If many points
       fall outside the confidence bands, there is evidence for a random effects
       analysis. Gaps are indicative of PUBLICATION BIAS.;

/*
dfile          name of the sas data file with data
es             name of variable in dfile with the effect size response variable
wgt            name of the weight variable in dfile. This needs to be the
               inverse of the "sampling variance" for each study
study          variable name for the labeled study (trial) in dfile
minprec        Minimum precision value used in the graph (set by trial and error, so
               that the full range of data is encompassed by the curves
maxprec        Maximum precision value used in the graph (set by trial and error, so
               that the full range of data is encompassed by the curves
numb           Number of precision values to make from minprect to maxprec (default25)

Macro creates various variables and data files starting with the underline symbol (_).
As a precaution, it is best if you do not have any variables or file names that
start with this symbol. Macro also overwrites titles starting at title2.
One can ignore tabular output here (just use the plots). Graphs are made with
the new SGPLOT procedure, which requires sas 9.2 or later.

After running the macro, the data files _pred1s and _funnel are available for
further use, if desired.
*/
```

…

Example: %***funnel***(dfile=shah,es=slope,wgt=wgt,study=study,minprec=**2**,maxprec=**70**);

```
%macro Probnewstudy(meanES=,SIGMA2=,numb=20,minT=,maxT=);
*---Experimental macro, provided as-is (that is, with no warranty).;

*---Determine probability that a randomly selected study has an Effect Size
       greater (less) than the constant _T, based on the meanES and between-study
       variance from a random-effects meta-analysis. Method described in Madden and Paul
       (Phytopathology 101:16-30 [2011]).
       Key references given in that paper. Macro written by L. Madden. ;
*---Macro overwrites title2 and higher.;

/*
meanES        Mean (expected) Effect Size. Use meanES estimated from a
              random-effects meta-analysis
SIGMA2        Among-study variance (from a random-effects meta-analysis)
minT          Minimum value of Effect-Size Constant considered
maxT          Maximum value of Effect-Size Constant considered
numb          Number of constant Effect Sizes between minT and maxT (default is 20)
              (one actually gets one more than the value of numb)

Results are put in the data file _gener, which can be accessed after running the macro,
if desired.
*/
```

…

Example: %*Probnewstudy*(meanES=.515,minT=0,maxT=.7,SIGMA2=.1181);

```
%macro biasbound(dfile=,wgt=,SIGMA2=,plotbiasmax=,plotbiasref=,K=,new=);
*---Experimental macro, provided as-is (that is, with no warranty).;

*---Macro calculates the absolute value of the bias bound from a univariate meta-analysis,
       based on the method developed by Copas and Jackson. Basic concept: find the
       magnitude of the bias (upper limit) for the estimated effect size if there is from
       1 to NEW additional studies that were not included in the meta-analysis.;
*---Tabular and graphic output is generated.
       Results are stored in data file _gg0, which can be accessed after running the macro.;
*---Macro written by L. Madden.;

/*
dfile         Name of sas data file with effect sizes and related items
wgt           Weight variable (inverse of the "sampling variance") for each
              study. The same weight used in the meta-analysis
SIGMA2        Among-study variance (estimated from a random-effects meta-analysis)
plotbiasmax   Maximum "y value" in the graph of |bias bound| vs. # of unrepored studies.
              Good choice: absoulte value of the mean ES estimated from the random-effects
              meta-analysis.
plotbiasref   A horizontal reference line on the graph. Could be the absolute value of
              lower 95% confidence limit for mean ES. If you don't want a reference
              line, then give a plotbiasref value greater than plotbiasmax.
K             Number of studies in the actual meta-analysis.
new           Maxinum number of "additional" studies that could exist. The bias
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                bound is found for 1-->new additional studies.
                One choice for NEW: if the original meta-analysis was based on K studies,
                then also use K for NEW.

                If the bias-bound curve does not cross or come too close to the mean
                ES, then publication bias is likely not too much of a concern.
*/

…
```

Example: %***biasbound***(dfile=shah,wgt=wgt,SIGMA2=**.1181**,K=**20**,
new=**20**,plotbiasmax=**.52**,plotbiasref=**.34**);

```
%macro metapower(meanES=,SE=,K=,dfAdjust=1,alpha=0.05,nullmu=0);
title2 'Power analysis for random-effects meta-analysis (1- and 2-sided)';
*---Experimental macro, provided as-is (that is, with no warranty).;
*---Determine the power of the meta-analysis to detect true non-null effects, if one
        had another set of K studies with the same results, with the assumption that
        the null hypothesis (of no effect) is false (i.e., so that the alternative
        hypothesis is true).;
*---The null hypothesis is              Ho: ES = nullmu

        Alternative hypothesis is:      Ha: ES ne nullmu    (not equal)   , or
                                        Ha: ES >  nullmu                  , or
                                        Ha: ES <  nullmu
        All three Ha hypotheses are evaluated. Note that a large number of
        decimal places are displayed, so that one can compare different scenarios.
;

/*
meanES          Mean (expected) Effect Size. Use meanES estimated from a random-effects
                meta-analysis
SE              Standard Error of estimated Effect Size (from a random-effects meta-analysis)
K               Number of studies in the meta-analysis
alpha           Pre-determined type I error rate constant (usually 0.05). That is, if one
                is performing a test of Ho: ES = nullmu with the chosen alpha.
nullmu          Constant value of the null hypothesis, that is, Ho: ES = nullmu
dfAdjust        df for the hypothesis test is based on number of studies minus dfAdjust.
                Typically, this is df = K - dfAdjust, and dfAdjust=1. However, some
                argue for more stringent conditions (e.g., dfAdjust=2).

Results are put in the data file _fullpower, which can be accessed after running the macro,
if desired.
*/

…
```

Example: %***metapower***(meanES=.515,SE=.0856,K=20,alpha=0.05,nullmu=0);

```
%macro metapower2(meanES=,SE=,K=,dfAdjust=1,alpha=0.05,
        nullmumin=0,nullmumax=,numb=25);
title2 'Power analysis for random-effects meta-analysis (1- and 2-sided)';

*---Experimental macro, provided as-is (that is, with no warranty).;
*---Determine the power of the meta-analysis to detect true non-null effects, if one
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      had another set of K studies with the same results, with the assumption that
      the null hypothesis (of no effect) is false (i.e., so that the alternative
      hypothesis is true).;
*---The null hypothesis is               Ho: ES = nullmu

      Alternative hypothesis is:         Ha: ES ne nullmu    (not equal)   , or
                                         Ha: ES >  nullmu                  , or
                                         Ha: ES <  nullmu
      All three Ha hypotheses are evaluated. Note that a large number of decimal
      places are displayed, so that one can compare different scenarios.

      A range of values for the expected value under the null hypothesis (nullmu)
      is considered, from nullmumin to nullmumax. In other words, this macro is the
      same as metapower, except that multiple values of nullmu are evaluated.;

*---Results are stored in data file _fullpower2, which can be accessed after
      running the macro.;

/*
meanES        Mean (expected) Effect Size. Use meanES estimated from a
              random-effects meta-analysis
SE            Standard Error of estimated Effect Size (from a random-effects meta-analysis)
K             Number of studies in the original meta-analysis
alpha         Pre-determined type I error rate constant (usually 0.05). That is, if
              one is performing a test of Ho: ES = nullmu with the chosen alpha.
nullmumin     Smallest mean ES under Ho (ES = nullmu) considered
nullmumax     Largest mean ES under Ho (ES = nullmu) considered
dfAdjust      df for the hypothesis test is based on number of studies minus dfAdjust.
              Typically, this is df = K - dfAdjust, and dfAdjust=1. However, some
              argue for more stringent conditions (e.g., dfAdjust=2).
numb          Number of distinct nullmeans evaluated (between nullmumin and nullmax)
              Default of 25 values.

Graph made with the SGPLOT procedure (requires sas 9.2 or later).

*/

…
```

Example: ***%metapower2***(meanES=.515,SE=.0856,K=20,alpha=0.05,
nullmumin=.0,nullmumax=.75);

```
%macro metapower3(meanES=,SE=,alpha=0.05,nullmu=0,Korig=,Kmin=2,Kmax=);
title2 'Power analysis for random-effects meta-analysis (1- and 2-sided)';
*title3 '(range of number of studies for identified ES under the null hypothesis)';

*---Experimental macro, provided as-is (that is, with no warranty).;
*---Determine the power of the meta-analysis to detect true non-null effects, if one
      had another set of K studies with the same results, with the assumption that
      the null hypothesis (of no effect) is false (i.e., so that the alternative
      hypothesis is true).;
*---The null hypothesis is               Ho: ES = nullmu

      Alternative hypothesis is:         Ha: ES ne nullmu     (not equal), or
                                         Ha: ES >  nullmu                  ,or
                                         Ha: ES <  nullmu
      All three Ha s are evaluated. Note that a large number of decimal places are displayed,
      so that one can compare different scenarios.

      A range of number of studies (K) is considered (from Kmin to Kmax), all for one
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```
       null-hypothesis mean (nullmu). Separate results for K: Kmin-->Kmax. This macro is the
       same as %metapower, except that a range of K values are considered.;
*---The macro is based on the "theoretical power" calculations shown in Madden
       and Paul (2011). A more accurate approach is based on simulation (also described in
       Madden and Paul), but this macro does not do the latter.;

*---Macro also calculates the 95% confidence interval for the expected effect size for
       all K values between Kmin and Kmax.;

*---Results are stored in data file _fullpower3, which can be accessed
       after running the macro.;

/*
meanES        Mean (expected) Effect Size. Use meanES estimated from a
              random-effects meta-analysis
SE            Standard Error of estimated Effect Size (from a random-effects meta-analysis)
Korig         Original number of studies (K) in the meta-analysis that results in meanES and SE
Kmin          Minimum number of studies in the original meta-analysis
Kmax          Maximun number of studies in the meta-analysis
alpha         Pre-determined type I error rate constant (usually 0.05). That is, if one is
              performing a test of Ho: ES = nullmu with the chosen alpha.
nullmu        Constant value of the null hypothesis, that is, Ho: ES = nullmu
dfAdjust      df for the hypothesis test is based on number of studies minus dfAdjust.
              Typically, this is df = K - dfAdjust, and dfAdjust=1. However, some
              argue for more stringent conditions (e.g., dfAdjust=2).

Graph made with SGPLOT procedure (requires sas 9.2 or later).
*/
…
```

Example: ***%metapower3***(meanES=**.515**,SE=**.0856**,alpha=**0.05**,nullmu=**.25**,
Kmin=**2**,Kmax=**25**,Korig=**20**);

```
*---Forest plot using the SGPLOT procedure;
*---Now control the lower and upper limits because of the wide intervals above;
proc sgplot data=shah;
title2 'Forest plot';
scatter x=slope y=study / xerrorlower=lowerlimit xerrorupper=upperlimit
             markerattrs=(color=blue symbol=squarefilled size=9pt)
             errorbarattrs=(color=blue pattern=1 thickness=1);
refline 0 / axis=x lineattrs=(color=black pattern=1 thickness=1.5);
                         *<^-reference line (null hypothesis);
xaxis max= 4 min=-2 label="Slope for yield loss";
                         *<^-cut off the extemes of CIs for one study;
yaxis type=discrete discreteorder=data label="Study";
run;
```
