The impact of lime and farming systems on sole-cropped and intercropped maize

Introduction

There are four key questions.

1) Is maize responsive to lime in region III?

2) Are conservation farming basins and conservation farming permanent ridges effective farming systems in region III?

3) Is maize intercropped and rotated in situ with sunnhemp as viable as sole-cropped maize rotated with groundnuts?

4) and is there any evidence of the rotation with groundnuts increasing sole-cropped maize yields?

Data

Table 1 shows the distribution of maize yields in region III zone, from the treatments of 61 trials. From the 365 recorded treatments, the average yield was 3,020kg ha^{-1} with a standard deviation of 1,675kg ha^{-1}. The median is 2,721kg ha^{-1}, which is lower and suggests a small number of farmers had higher yields than normally expected. The highest yield was 11,762kg ha^{-1}.

Table 1 shows the distribution of maize yields in region III zone, from the treatments of 61 trials.

	n	Mean	Median	StDev
Yield	365	3019.7	2721.1	1674.8

Farming systems and maize/red sunnhemp

The trials are in the form of three-factor experiments, 2^3. The three factors are the farming systems of conservation farming basins, conventional farming practice and conservation farming permanent ridges. The two levels are maize and maize intercropped with red sunnhemp. Table 2 shows the yields and standard deviations of the different treatments in the 2^3 trial. The two levels, maize and maize/red sunnhemp intercrop, are quite distinct. At the maize level, the average yield for conservation farming basins is 4,187kg ha^{-1} with a standard deviation of 1,830kg; for conventional farming practice the average yield is 3,583kg ha^{-1} with a standard deviation of 1,654kg; and for conservation farming permanent ridges, 4,012kg ha^{-1} with a standard deviation of 1,366kg ha^{-1}. At the maize/red sunnhemp level, the conservation farming basins yielded 2,189kg ha^{-1} with a standard deviation of 1,228kg; the mean yield from conventional farming practice was 1,917kg ha^{-1}; and the yield from conservation farming permanent ridges is 2,183kg ha^{-1} with a standard deviation of 992kg ha^{-1}. In a simple analysis, the hypothesis that there is no difference between the yields fails to be rejected.

Table 2 shows the yields and standard deviations of the different treatments in the 2^3 trial. The two levels, maize and maize/red sunnhemp intercrop, are quite distinct.

```
ANALYSIS OF VARIANCE ON Yield
SOURCE     DF        SS        MS        F       p
Treatments  5 320588000  64117600    32.86    0.000
ERROR     359 700448768   1951111
TOTAL     364 1.021E+09
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -----+---------+---------+---------+-
CFBMaize   61      4187      1830                         (---*--)
CFPMaize   61      3583      1654                   (---*--)
CBRMaize   62      4012      1366                        (--*---)
CFBM/RSH   60      2189      1228     (---*--)
CFPM/RSH   60      1917      1116   (--*---)
CFRM/RS    61      2183       992     (---*--)
                                   -----+---------+---------+---------+-
POOLED STDEV =     1397              2000      3000      4000      5000
```

Table 3 shows the distributions of yields of maize with red sunnhemp as an intercrop, and solecropped maize. At the two different levels, maize intercropped with sunnhemp has a yield of 2,097kg ha^{-1} with a standard deviation of 1,117kg, whereas the sole-cropped maize has a yield of 3,928kg ha^{-1} with a standard deviation of 1,638kg. Perhaps unsurprisingly, there is a significant difference between the two yields.

Table 3 shows the distributions of yields of maize with red sunnhemp as an intercrop, and solecropped maize.

```
ANALYSIS OF VARIANCE ON Yield
SOURCE     DF        SS        MS        F       p
M v. M/RSH  1 305883712 305883712   155.26    0.000
ERROR     363 715153024   1970119
TOTAL     364 1.021E+09
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ---+---------+---------+---------+---
Maize     181      2097      1117  (--*--)
Maize/RSH 184      3928      1638                            (--*--)
                                   ---+---------+---------+---------+---
POOLED STDEV =     1404            2100      2800      3500      4200
```

Table 4 shows the distribution of maize yields from conservation farming basins, conventional farming practice and conservation farming permanent ridges. The average yield from the conservation farming basins is 3,196kg ha^{-1} with a standard deviation of 1,850kg; from conventional farming practice, 2,757kg ha^{-1} with a standard deviation of 1,637kg; and from conservation farming permanent ridges, 3,105kg ha^{-1} with a standard deviation of 1,504kg. At a ten per level of significance, ANOVA fails to accept the null hypothesis of no difference between the mean yields.

Table 4 shows the distribution of maize yields from conservation farming basins, conventional farming practice and conservation farming permanent ridges.

```
ANALYSIS OF VARIANCE ON Yield
SOURCE     DF        SS        MS        F        p
Systems     2  13039283   6519642     2.34    0.098
ERROR     362 1.008E+09   2784523
TOTAL     364 1.021E+09
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ---------+---------+---------+-------
CFBasins  121      3196      1850                   (---------*--------)
CFPract   121      2757      1637   (---------*---------)
PermRidge 123      3105      1504                (--------*---------)
                                   ---------+---------+---------+-------
POOLED STDEV =     1669                  2700      3000      3300
```

Lime and maize/ sunnhemp trial

The same trial is used to assess the impact of lime on maize and maize/red sunnhemp. Table 5 shows the distribution of maize yields with and without lime. The yield without lime is 2,757kg ha^{-1} with a standard deviation of 1,637kg and with lime, 3,150kg ha^{-1} with a standard deviation of 1,681kg. The null hypothesis that the mean yields with and without lime are the same fails to be accepted, and the unadjusted increase in yield from lime is 14.24 per cent.

Table 5 shows the distribution of maize yields with and without lime.

```
ANALYSIS OF VARIANCE ON Yield
SOURCE     DF        SS        MS        F        p
Lime        1  12528525  12528525     4.51    0.034
ERROR     363 1.009E+09   2778260
TOTAL     364 1.021E+09
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --+---------+---------+---------+----
W/o lime  121      2757      1637   (-----------*-----------)
Lime      244      3150      1681                       (-------*-------)
                                   --+---------+---------+---------+----
POOLED STDEV =     1667            2500      2750      3000      3250
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Table 6 shows the distributions of maize yields from Northern and Copperbelt regions. The average yield in Northern region is 3,330kg ha^{-1} with a standard deviation of 1,687kg, and from the Copperbelt region, the yield is 2,740kg ha^{-1} with a standard deviation of 1,618kg. The null hypothesis that there is no difference between the yields fails to be accepted, and Northern region yields 21.5 per cent more than the Copperbelt.

Table 6 shows the distributions of maize yields from Northern and Copperbelt regions.

```
ANALYSIS OF VARIANCE ON Yield
SOURCE     DF        SS        MS        F        p
Region      1  31759556  31759556    11.65    0.001
ERROR     363 989277184   2725281
TOTAL     364 1.021E+09
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -------+---------+---------+---------
Northern  173      3330      1687                       (-------*-------)
Cubelt    192      2740      1618   (------*-------)
                                   -------+---------+---------+---------
POOLED STDEV =     1651                2700      3000      3300
```

Table 7 shows the distributions of maize yields based on trial age. The yield for farmers starting this last season is 3,047kg ha^{-1} with a standard deviation of 1,748kg. Farmers with one year's experience yielded 2,967kg ha^{-1} with a standard deviation of 1,528kg. There is no significant difference between them this season.

Table 7 shows the distributions of maize yields based on trial age.

```
ANALYSIS OF VARIANCE ON Yield
SOURCE     DF        SS        MS        F        p
TrialAge    1    513521    513521     0.18    0.669
ERROR     363 1.021E+09   2811359
TOTAL     364 1.021E+09
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -------+---------+---------+---------
     0    241      3047      1748           (---------*----------)
     1    124      2967      1528   (-------------*--------------)
                                   -------+---------+---------+---------
POOLED STDEV =     1677                2800      3000      3200
```

Methodology

Lime with maize and maize/red sunnhemp intercrop

Lime is the factor. The levels are sole-cropped maize rotated with groundnuts and the maize/red sunnhemp intercrop rotated *in situ*. The interaction of the factor and level is examined. The site mean is used to proxy sites and is used as a covariate to examine the interactions between the factor and the site mean and the levels and site mean. Studentised residuals are used to identify outliers, which are then omitted from the general linear model.

Farming systems with maize and maize/ sunnhemp intercrop

The systems are the factors, which are conservation farming basins, conventional farming practice and conservation farming permanent ridges, and the levels are sole-cropped maize and maize intercropped with sunnhemp. The analysis is similar to the 2^2 analysis above, only that this is a 2^3 analysis. The difference between the factors is examined by applying restrictions on a regression model and testing the difference in residual sum of squares.

Results

Lime with maize and maize/red sunnhemp intercrop

Table 8 shows the results of a general linear model for the lime factor and the maize and maize/red sunnhemp levels. The maize yield with lime is significantly different from the maize yield without lime, with an F-statistic of 44.15, which is way over the critical level at one and 339 degrees of freedom. This suggests that lime increases the adjusted mean yield of 2,618kg ha^{-1} to 3,070kg ha^{-1}, an increase of 17.26 per cent. These yields are lower than the uncontrolled means of 2,757kg ha^{-1} and 3,150kg ha^{-1}, but the increase in yield attributable to lime is higher than the unadjusted increase of 14.24 per cent. Figure 1 shows the difference in maize yields with and without lime. The green line is the yield without lime, the red line is with lime and the blue line is with lime after deducting the cost of the lime.

The maize yield from the maize/red sunnhemp intercrop is significantly different from the yield from the sole-cropped maize, with an F-statitic of 811.11. Figure 2 shows the differences between the maize/red sunnhemp yields (green lime) and the sole-cropped maize (red line). The black line is the added-back savings from the intercropped treatment. The adjusted maize/red sunnhemp yield is 1,946kg ha^{-1}, which compares with the sole-cropped yield of 3,743kg ha^{-1}. There is a 48 per cent decrease in mean yield.

There is no significant interaction between lime and the maize and maize/sunnhemp levels, and there is no significant interaction between lime and the site mean, which can be seen by the lack of divergence in the fitted lines in Figure 1. The interaction between sole-cropped maize and intercropped maize, and the site mean is however significant with an F-statistic of 55.14. The divergence can be clearly seen in Figure 2, which suggests that farmers increasingly benefit from sole-cropped maize over intercropped maize as their farm management ability increases.

Table 8 shows the results of a general linear model for the lime factor and the maize and maize/red sunnhemp levels.

F-test with denominator: Error
Denominator MS = 354289 with 339 degrees of freedom

Numerator	DF	Seq MS	F	P
Sitemean	1	3.10E+08	875.57	0.000
Lime	1	15641309	44.15	0.000
MaizeSun	1	2.87E+08	811.11	0.000
Lime*MaizeSun	1	460820	1.30	0.255
Lime*Sitemean	1	588823	1.66	0.198
MaizeSun*Sitemean	1	19534120	55.14	0.000

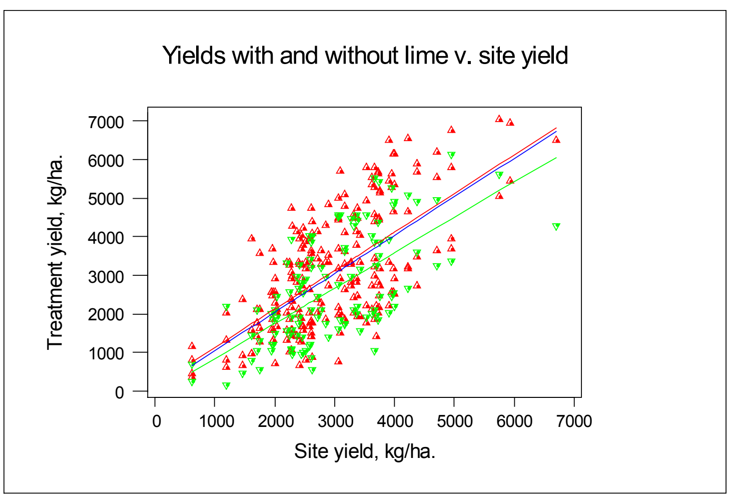

Figure 1 shows the difference in maize yields with and without lime. The green line is the yield without lime, the red line is with lime and the blue line is with lime after deducting the cost of the lime.

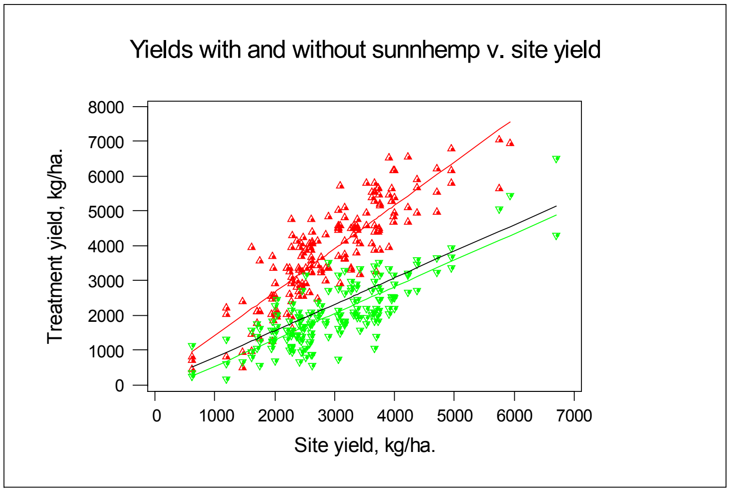

Figure 2 shows the differences between the maize/red sunnhemp yields (green lime) and the sole-cropped maize (red line). The black line is the added-back savings from the intercropped treatment.

Table 9 shows the regression results of yields on the sitemean, with a dummy constant and coefficient for the sole-cropped maize. The constant is not important, but the significant DConstant implies an average increase of 402.7kg ha^{-1} of sole-cropped maize over the intercropped maize, and the DSitemean coefficient implies a further 39 per cent increase that is a function of farmer management ability.

Table 9 shows the regression results of yields on the sitemean, with a dummy constant and coefficient for the sole-cropped maize.

```
The regression equation is
Yield = - 225 + 0.760 Sitemean + 403 DConstant + 0.484 DSitemean

Predictor        Coef       Stdev    t-ratio        p
Constant       -225.0       150.8      -1.49    0.136
Sitemean      0.75988     0.04823      15.76    0.000
DConstant       402.7       215.4       1.87    0.062
DSitemean     0.48387     0.06962       6.95    0.000

s = 632.9       R-sq = 81.8%     R-sq(adj) = 81.7%
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Farming systems with maize and maize/ sunnhemp intercrop

Table 10 shows the results of a general linear model for the three farming systems and the two levels of sole-cropped maize and intercropped maize. The systems are significantly different with an F-statistic of 22.3. The interaction of the farming system with the difference levels, the sole-cropped and intercropped maize, is not however significant, which means no difference in yield performance of the farming system can be attributed to whether the maize was sole-cropped or intercropped in sunnhemp.

Table 10 shows the results of a general linear model for the three farming systems and the two levels of sole-cropped maize and intercropped maize.

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F-test with denominator: Error
Denominator MS =  342437 with 334 degrees of freedom

Numerator            DF   Seq MS       F        P
Sitemean              1 3.22E+08 940.07   0.000
Systems               2  7636072  22.30   0.000
MaizeSun              1 2.74E+08 801.10   0.000
Systems*MaizeSun      2   100606   0.29   0.746
Systems*Sitemean      2  1910466   5.58   0.004
MaizeSun*Sitemean     1 17609612  51.42   0.000
```

The systems do however significantly interact with the sitemean with an F-statistic of 5.58, which suggests that the systems perform according to farmer ability. Figure 3 shows the yields of conservation farming basins (red), conventional farming practice (green) and permanent basins (blue), together with their fitted values. It appears that both conservation farming basins and conservation farming permanent ridges are superior to conventional farming practice.

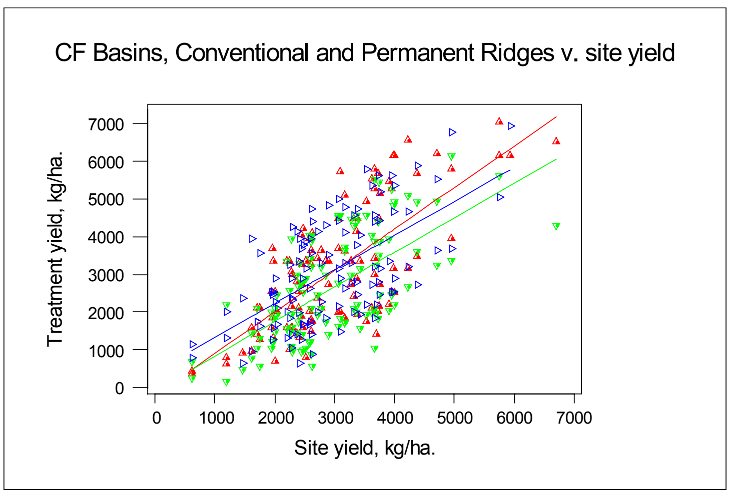

Figure 3 shows the yields of conservation farming basins (red), conventional farming practice (green) and permanent basins (blue), together with their fitted values.

Table 11 shows the regression of yield on sitemean and dummy constants and coefficients representing conservation farming basins and permanent ridges. Conventional farming practice is included in the constant term and the sitemean coefficient. On omitting the conservation farming basin dummy coefficient and constant variables CFSM and CF, the hypothesis that conservation farming basin system is no different to conventional farming practices fails to be accepted with an F-statistic of 10.2001 (p= 0.0008). The implication of this finding is that the conservation farming basin system significantly increases maize yields from an adjusted 2,624kg ha^{-1} expected from conventional farming systems in region III to 3,063kg ha^{-1}, an increase of 16.7 per cent.

Omitting the PRSM and PR dummy coefficient and constant variables, to test the hypothesis that their is no difference between conventional farming practice and conservation farming permanent ridge culture also fails to be accepted, with an F-statistic of 10.1631 (p=0.0008). The result suggests that using the conservation farming permanent ridge culture instead of the conventional farming practice in region III, significantly increases maize yields from an adjusted 2,624kg ha^{-1} to 3,093kg ha^{-1}, and increase of 17.9 per cent.

Omitting the conventional farming dummy constant and coefficient variables to test the hypothesis that there is no difference between the conservation farming basins system and the permanent ridge culture fails to be rejected, however, with an F-statistic of 1.9000 (p= 0.1118). This finding suggests that there is little to distinguish between the yields from the conservation farming basin system and from the conservation farming permanent ridge culture.

Table 11 shows the regression of yield on sitemean and dummy constants and coefficients representing conservation farming basins and permanent ridges. Conventional farming practice is included in the constant term and the sitemean coefficient.

Yield = - 74 + 0.915 Sitemean + 0.182 CFSM - 113 CF - 0.016 PRSM + 507 PR

Predictor	Coef	Stdev	t-ratio	p
Constant	-74.0	324.1	-0.23	0.820
Sitemean	0.9150	0.1045	8.75	0.000
CFSM	0.1821	0.1441	1.26	0.207
CF	-112.8	450.1	-0.25	0.802
PRSM	-0.0158	0.1498	-0.11	0.916
PR	506.6	462.0	1.10	0.274

s = 1098 R-sq = 45.5% R-sq(adj) = 44.7%

The yield in the maize/sunnhemp treatments is significant different from the yield in the sole-cropped maize, with an F-statistic of 801.10. The yield from the intercropped treatment is 2,030kg ha^{-1}, in comparison with 3,823kg ha^{-1}. The result suggests that yields are 46.9 per cent lower in the treatment with maize intercropped with sunnhemp than in the sole-cropped maize. It should be noted that this is at half the maize plant density per hectare, and it appears that the yield per plant or station in the intercropped maize is higher than the sole-cropped maize by 6.2 per cent.

Conclusions

1) Maize yield in region III increases by 17.3 per cent in response to lime.

2) Conservation farming basins increases maize yields over conventional farming practice by 17 per cent. Conservation farming permanent ridges increases maize yields over conventional farming practice by 18 per cent. There is no difference between yields from conservation farming basins and permanent ridges.

3) The yield from the maize intercropped with sunnhemp and rotated *in situ* is 48 per lower than sole-cropped maize rotated with groundnuts in the lime analysis and 47 per cent lower in the farm systems analysis, on a per hectare basis.

4) The yield from the maize intercropped with sunnhemp and rotated *in situ* is 6.2 per cent higher than sol-cropped maize on a per planting station or plant basis.

5) There is no evidence that maize yields rise because of the groundnut rotation over the two years of the trial, and it may be premature.

6) Since the use of conservation farming method is synonymous with using lime, and lime was not used on the conventional farming plot, it cannot be determined whether it is the conservation farming method or the lime that increases yields.

These findings apply to region III agro-ecological zones only.