THE NEED FOR STATISTICAL ANALYSIS OF ON-FARM EXPERIMENTS;

STATISTICAL ANALYSIS AS THE BASIS OF AGRONOMIC, ECONOMIC AND FARMER ASSESSMENT

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The need for statistical analysis of on-farm experiments; statistical analysis as the basis of agronomic, economic and farmer assessment[1]

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ABSTRACT

Variability among farms is often high. This frequently results in interactions between experimental treatments and farms. A combined statistical analysis of the experimental results across farms will reveal such interactions, and prevent undue generalizations in recommendations to farmers. The case of an on-farm experiment on the level of fertilizer application in maize - with 10 farmers and 2 replications within-farm - is presented in order to demonstrate the need for thorough statistical analysis. A coefficient of variation of 10.4 % for the combined analysis across farms shows that reliable results can be obtained in on-farm experiments. With careful positioning of the blocks in farmers' fields and standardized harvesting procedures credible results can be obtained. The computer programme used for the statistical analysis - MSTAT - calculates most F-values in combined analyses in a wrong way; this anomaly can be circumvented by using the option 'Custom Design'.

INTRODUCTION

In this paper an experiment examining the level of fertilizer application in maize is discussed in order to demonstrate the need for thorough statistical analysis. The experiment was implemented in the season 1994/95 and it concerns a determinative Researcher-Managed Farmer-Implemented (RMFI) on-farm experiment. The following treatments were included:

1. 150/150 kg/ha = 6 bags/ha
2. 100/200 kg/ha = 6 bags/ha
3. 100/150 kg/ha = 5 bags/ha
4. 150/200 kg/ha = 7 bags/ha

The types of fertilizer used are D-compound (10-20-10) as basal dressing, and urea as top-dressing. In this experiment the effect of two levels of basal dressing (100 and 150), two levels of top-dressing (150 and 200) and their interaction can be determined. The starting point in this trial is treatment 1 which is the farmers' level of fertilizer application in the past two seasons (based on FSRT-WP monitoring data). Treatment 2 is the actual FSRT-WP recommendation to farmers in the area under study. The treatments 3 and 4 complement this 2^2 factorial, and comprise one bag of fertilizer less and one bag more respectively.

The experimental design is a Randomized Complete Block Design (RCBD) with 2 replications within each farm, on 10 farms.

DISCUSSION OF RESULTS

Statistical analysis

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[1] Paper presented at SAAFSR-E Conference, 2-4 October 1995, Harare

The Analysis of Variance (ANOVA) tables for each of the 10 trials (the within-site analyses) were constructed. In table 1 the coefficients of variation (cv's) of these 10 within-site analyses are presented. Three of the cv's are close to or above the 20 % level. These locations are omitted from the across-locations/ combined analysis since the high cv's can be explained, and the causes of the high cv's are not related to the experimental treatment.

Table 1: cv's of within-site analyses

Location	Coefficient of variation	New numbering
1	6.8 %	1
2	5.0	2
3	11.8	3
4	16.7	4
5	9.2	5
6	19.8 *	
7	14.9	6
8	6.8	7
9	24.2 *	
10	36.7 *	

* omitted from the combined analysis

At location 6 (cv = 19.8) two plots were infested with witchweed which resulted in low yield levels, and in one of these plots the Technical Assistant made an error in recording the yield of the sampling area. Since the witchweed infestation cannot be directly related to the fertilizer level and shows a very localized appearance, elimination of this experiment from the combined analysis is justified.

At location 9 (cv = 24.2) block 2 got waterlogged which resulted in a significant block/replication effect. The F-values of all treatment effects were very small.
At location 10 (cv = 36.7) one plot was infested with witchweed and hardly yielded anything. The crop was also planted late (early January). With a missing value estimate for the witchweed-infested plot the cv remained high (36.7 %).

Table 1 shows that the cv's of most on-farm experiments were low. This was mainly achieved through careful positioning of blocks in the farmers' fields and standardized harvesting procedures. At harvesting time the maize cobs were immediately shelled on the trial site, the seed was weighed and the moisture content determined with a moisture meter.

In order to establish whether a combined analysis across locations can be done, first the homogeneity of variances has to be determined. Bartlett's test is used for this purpose (see Neeley et al. 1991). Since Bartlett's test value was non-significant homogeneity of variances was assumed[2].

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[2] More details of the statistical analysis can be found in: Annual Report FSRT-WP, 1994/95, Part II - Trial Reports,

Combined Analysis

The computer programme MSTAT was used for the statistical analysis of this experiment. A combined analysis across the 7 locations generated by the MSTAT function FACTOR is presented here below.

Experiment Model Number 15:
One Factor Randomized Complete Block Design Combined over Locations
Factorial ANOVA for the factors:
Location with values from 1 to 7
Replication with values from 1 to 2
Factor A (treatment) with values from 1 to 4

Table 2: ANOVA-combined analysis

```
  K                 Degrees of   Sum of         Mean          F
Value    Source       Freedom    Squares       Square       Value     Prob
-----------------------------------------------------------------------------
  1     Location         6  26470561.233   4411760.205      2.3504   0.1441
 -3     Error            7  13139290.181   1877041.454
  4     Factor A         3   4626825.660   1542275.220      4.6411   0.0122
  5     LA              18  13817408.946    767633.830      2.3100   0.0340
 -7     Error           21   6978465.925    332307.901
-----------------------------------------------------------------------------
        Total           55  65032551.944
-----------------------------------------------------------------------------
     Coefficient of Variation: 10.42%
```

In above ANOVA table the F-value for the Factor A (Trt) effect is the ratio MS(Factor A)/MS(Error). This is not correct; in this combined analysis the appropriate ratio should be MS(Factor A)/MS(LA) = 1542275/767633 = 2.009 with a Prob=0.148.
In combined analyses the MSTAT function Factor is calculating all F-values by using the MS (Error) in the denominator. This anomaly can be corrected by using the Custom Design option under FACTOR as will be shown later.

The treatment effect is significant at the 0.15 level, and the interaction Location x Trt is significant at the 0.03 level. The significant interaction implies that no straightforward conclusions on main treatment effects can be made. Also pooling of the interaction and Error cannot be done. In graph 1 at the end of this paper one can see the interaction Location x Trt expressed in the frequent crossing of the four lines.

In the next two tables the mean yield levels at the 7 farms and the mean yields of the 4 treatments are given. The significant interaction Location x Trt calls for caution in the interpretation of the figures in table 4.

Mongu, p.10-23.

Table 3: Mean yield levels at 7 farms

Location	Yield in ton/ha at 14 % mc
1	5.4
2	6.1
3	4.3
4	5.2
5	6.1
6	5.1
7	6.4
Grand mean	5.5

Table 4: Mean yields of the 4 treatments

Treatment	Mean yield in ton/ha at 14 % mc
1	5.5
2	5.5
3	5.2
4	6.0

In order to partition the Trt effect in a basal, top and basal x top effect another MSTAT function - FACTOR, Number 19 - was run. The results are shown here below.

Experiment Model Number 19:
Two Factor Randomized Complete Block Design Combined over Locations
Factorial ANOVA for the factors:
Location with values from 1 to 7
Replication with values from 1 to 2
Factor A (basal) with values from 1 to 2
Factor B (top) with values from 1 to 2

In the following ANOVA table all sources of variation are tested against the Error term, which for Location, Factor A (basal), Factor B (top) and AxB is not correct. These sources should have been tested against R(L), LA, LB and LAB respectively. This will be done in the following MSTAT run (Custom Design).

In the ANOVA table the three-way-interaction LAB is significant at the 0.11 level, and the F-value is larger than 1.5. Since this indicates that there could be an interaction effect, we do not pool this interaction term with Error.

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     Table 5: ANOVA-combined analysis

  K                 Degrees of   Sum of          Mean          F
Value    Source       Freedom    Squares        Square       Value     Prob
-----------------------------------------------------------------------------
  1     Location          6  26470561.233   4411760.205    13.2761   0.0000
  3     R(L)              7  13139290.181   1877041.454     5.6485   0.0009
  4     Factor A          1   2268450.020   2268450.020     6.8263   0.0163
  5     LA                6   1204262.749    200710.458     0.6040
  8     Factor B          1   2208811.571   2208811.571     6.6469   0.0175
  9     LB                6   8635292.987   1439215.498     4.3310   0.0054
 12     AB                1    149564.069    149564.069     0.4501
 13     LAB               6   3977853.210    662975.535     1.9951   0.1120
-15     Error            21   6978465.925    332307.901
-----------------------------------------------------------------------------
        Total            55  65032551.944
-----------------------------------------------------------------------------
     Coefficient of Variation: 10.42%
```

The next table gives the main effects of basal and top dressing.

Table 6: Main effects of basal and top dressing (mean yields in ton/ha)

Main basal effect	Main top effect
1. 5.3 2. 5.7	1. 5.3 2. 5.7

In the next MSTAT run the option 'Custom Design' under the function FACTOR is used. With this option one can define the K-values according to one's own wishes, and in that way generate more appropriate denominators for the various F-values (the MSTAT manual is not very user-friendly in its explanations on how to handle this topic; this has been explained in more detail in another paper: AM van Eijk 1995: The use of K-values in MSTAT).

Experiment Model Number 35: (Custom Design)
Factorial ANOVA for the factors:
Factor A (location) with values from 1 to 7
Factor B (replication) with values from 1 to 2
Factor C (basal) with values from 1 to 2
Factor D (top) with values from 1 to 2

The four new Error terms created in the next ANOVA table are the interaction terms from ANOVA table 5:

K Value	Source
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- 3	Error = R(L) = 1877041/332308 = 5.65 with Prob = 0.0009
- 5	Error = Loc x basal = 200710/332308 = 0.60
- 9	Error = Loc x top = 1439215/332308 = 4.33 with Prob = 0.005
-13	Error = Loc x basal x top = 662975/332307 = 1.99 with Prob.= 0.11

Table 7: ANOVA-combined analysis

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  K                  Degrees of   Sum of          Mean          F
Value    Source        Freedom    Squares         Square        Value     Prob
-----------------------------------------------------------------------------
  1     Factor A         6  26470561.233   4411760.205      2.3504   0.1441
 -3     Error            7  13139290.181   1877041.454
  4     Factor C         1   2268450.020   2268450.020     11.3021   0.0152
 -5     Error            6   1204262.749    200710.458
  8     Factor D         1   2208811.571   2208811.571      1.5347   0.2617
 -9     Error            6   8635292.987   1439215.498
 12     CD               1    149564.069    149564.069      0.22
-13     Error            6   3977853.210    662975.535
-15     Error           21   6978465.925    332307.901
-----------------------------------------------------------------------------
        Total           55  65032551.944
-----------------------------------------------------------------------------
     Coefficient of Variation: 10.4%
```

The location effect is significant at the 0.14 level only. The mean yield levels ranged from 4.3 to 6.4 ton/ha with an overall mean yield of 5.5 ton/ha (see table 3). These yield levels are high; we have to take into account that the experimental plots were small (harvesting area = 18 m^2), fresh hybrid seed was used, most experiments were well maintained, and that the rainfall distribution was quite favourable this season in Kaoma.
The Standard Error of a Difference (SED) for location means = √1877041*2/8 = 685. The t-value is 2.365 (two-sided, df=7, 0.05 level). t x SED = 1620. The difference between two location means should be at least 1.6 ton/ha in order to declare the two means significantly different.

The R(L) [replications within location or pooled replication] is very significant, implying that the positioning of blocks has been effective in reducing the experimental error. The overall cv of 10.4 % is not bad at all for on-farm experiments.

Since the location x basal interaction is non-significant, and the main basal effect is significant at the 0.01 level we have to conclude that the higher level of basal dressing yielded significantly more than the lower level. In other words, the basal application of 150 kg/ha yielded more than the 100 kg/ha application with most farmers. One additional bag of basal fertilizer resulted in 400 kg maize, or 4.4 bags of maize extra (see table 6). In graph 2 one can see that at 5 out of the 7 locations the extra basal dressing resulted in a higher yield, while at 2 locations the yields were more or less equal. The lack of effect at location 6 could be due to an irregular and low plantstand caused by ants. At location 7, the location with the highest overall yield, the farmer claims that it was too dry at the time of basal application.

The top dressing effect is only significant at the 0.26 level, while the interaction location x top is very significant. This implies that no overall top dressing effect can be claimed; the effects of top dressing differ per location. In graph 3 one can see that at the first two locations a negative effect occurs, in the next three ones a positive effect, and in the last two ones a very small positive and negative effect respectively.

The SED for comparing the two topdressing levels within each location = √332308*2/4 = 408. We use the MS of the last Error term in table 7 in this calculation, since the decision to compare topdressing levels within each location was based on the significant interaction effect location x top, which has this MS Error as denominator. The t-value = 1.721 (one-sided, df = 21, 0.05 level). t x SED = 702. It is only at the locations 4 and 5 that this value 702 is surpassed, which implies that only at these two locations a significant topdressing effect occurred. With a significance level of 0.10 (t-value = 1.323) the t x SED value = 540, which would result in a similar conclusion.

The significance levels of the topdressing effects in the within-site analyses are presented in the following table. This supports our conclusion that only at the locations 4 and 5 a significant topdressing effect occurred.

Table 8: Significance levels of topdressing effects

Location	Significance level of topdressing-effect
1	0.16
2	0.23
3	0.38
4	0.09
5	0.02
6	Ns
7	Ns

The timing of fertilizer application (a non-experimental factor in this trial) was set at 2 and 6 weeks after planting for basal and topdressing respectively. This is the current FSRT-WP recommendation. Farmers apply in general about two weeks later. We decided to 'impose' our timing recommendation in order to avoid confounding with the level of fertilizer application. 'Imposing' means here that the TAs made an appointment with the farmer when to apply the fertilizers. Since fertilizer should be applied under favourable weather conditions, a strict following of the recommended timings cannot - and should not - be done by the farmers.

In the next table the DAP (days after planting) for basal and topdressing are indicated, as well as the gap between basal and topdressing. The FSRT-WP recommendation is 14 and 42 DAP with a gap of 28 days. Because of dry weather conditions at the beginning of the season the basal was applied relatively late, which in most locations resulted in a short period between basal and top application. The lack of topdressing effect at all locations except 4 and 5 cannot be explained with these data. At the time of topdressing application the soil was moist at all locations.

Table 9: Days after planting for basal and topdressing

Location	DAP basal	DAP top	gap
1	28	45	17
2	17	34	17
3	28	45	17
4	27	43	16
5	27	43	16
6	19	44	25
7	17	42	25

One could argue that at the time of topdressing application the weeding issue becomes crucial in the sense that insufficient and late weeding overrules the effect of topdressing. In the research protocol sheets the TAs were requested to give a weed score at three different times in the growing period. These scores, however, do not clarify the interaction effect of location x topdressing. Also previous crop, earlier fertilizer use, planting date, disease/pest score and plant density do not offer explanations for the puzzling topdressing effect.

In the season 1993/94 a series of RMFI on-farm trials were implemented in the same area. In these experiments the treatments 100/100 and 100/200 were included with mean yield levels of 3.4 and 4.5 ton/ha (n=8). The overall yield level of the Trt 100/200 in the 1994/95 season was 5.5 ton/ha (n=7).
In the season 1993/94 there was no interaction location x top and the topdressing effect from 100 to 200 kg/ha was very significant. This season's trial, however, shows a significant interaction location x top and no significant main topdressing effect from 150 to 200 kg/ha. These inconsistent results call for further research.

In the season 1993/94 two additional bags of topdressing gave 1.1 ton of maize extra, while in the season 1994/95 one additional bag of topdressing gave on average 0.4 ton extra (from 5.3 to 5.7 ton/ha, see table 6). In the only two locations (4 & 5) with a really significant topdressing effect the yield increase was, however, 1.5 and 1.7 ton/ha. This shows how tricky it can be to base conclusions on mean yield figures across farmers without a proper statistical analysis.

When further research is undertaken to study the interaction location x top, it might be worthwhile to place simple rainfall gauges at each trial location since rainfall can be quite localized in the study area, and can determine the efficacy of fertilizer application (simple rainfall gauges can be made from hard plastic pipes with a thin layer of engine-oil on the water surface to prevent evaporation).

In ANOVA table 7 one can see that the basal x top interaction effect was non-significant.

The figures in the next table are extracted from table 4.

Table 10: Mean yield levels and mean response to N

basal	top	Trt	fertilizer (kg/ha)	Yield (t/ha)	Response to N
1	1	3	100/150 (79 kg N/ha)	5.2	66 kg grain/kg N
1	2	2	100/200 (102)	5.5	54
2	1	1	150/150 (84)	5.5	65
2	2	4	150/200 (107)	6.0	56

In above table Trt 1 is the farmer's level of application and Trt 2 is the current FSRT-WP recommendation. Both entail a total application of 6 bags/ha. Since the figures in above table are the averages of 7 locations with 2 replications/location, these numbers have to be interpreted with caution. At first sight one might conclude, for example, that the treatments 1 and 2 yield the same. Based on the statistical analysis, however, one should give preference to treatment 1. The reasoning goes as follows: since the location x basal interaction was non-significant but the location x top interaction very significant, means across farmers do not have much practical value. The non-significant location x basal interaction and significant main basal effect imply that extra basal gave on most farms a significantly higher yield. The significant location x top interaction, however, does not allow for such a forthright conclusion in the case of topdressing. Treatment 1 with the higher level of basal dressing and the lower level of topdressing would be a more secure recommendation in this case, based on the statistical analysis alone.
In another on-farm trial implemented in the same area in the season 1994/95 two levels of fertilizer application were involved. The level 150/150 applied at the recommended time yielded 5.5 ton/ha (n=6), which is exactly the same as in this experiment, while the level 100/100 given as a mixed application of basal and top at 6 weeks after planting yielded 4.4 ton/ha. The difference in yield between these two levels was significant at the 0.05 level.

As table 10 indicates the 150/150 application supplies in total 84 kg N/ha and gives a mean response of 65 kg grain/kg N. The application level 100/100 supplies 56 kg N/ha, and gives a mean response of 78 kg grain/kg N. This is a surprisingly high response considering that the basal and top dressings were given as a mixed application and at a late moment in the crop cycle. This practice of mixed application, which is quite common in the study area, cannot be denied some logic in the sense that the response to N is high.

The experiment with the two levels 100/100 and 150/150 suggests that at 84 kg N/ha the response curve already levels off. The mean responses to N given in table 10 indicate that N doses of more than 100 kg N/ha are beyond the steep, straight segment of the response curve. All this suggests that in future lower levels should be tested, for example the treatments 100/100 (56 kg N/ha), 150/100 (61 kg N/ha) and 100/150 (79 kg N/ha). It is likely that with smaller fertilizer doses (and a bit lower mean yield levels) high responses to N and other nutrients can be obtained. The 'old' blanket recommendation of 200/200 kg/ha, which was already lowered to 100/200 by FSRT-WP in the past two seasons, can probably be lowered even further.

Economic analysis

Since the main basal effect was significant, and no interactions location x basal and basal x top were observed, a partial budget analysis on the main basal effect has been done (CIMMYT 1988).
With a field price of Zambian Kwacha (ZKW) 13000 for a bag of basal, a field price of ZKW 5500 for a bag of maize, and a yield adjustment factor of 25 % the calculated Marginal Rate of Return (MRR) from the lower to the higher level of application is 41 %. With an annual inflation of 65 % and a period of 7 months from buying the fertilizer to selling the first maize, the minimum rate of return has been set at 90 % (38 % inflation plus 50 % minimum acceptable rate of return). Since the MRR is lower than the minimum rate of return it is unlikely that farmers would go for the higher level of basal application.

The partial budget analysis on the two levels of basal application, together with the hitherto unexplained interaction location x top, suggests that treatment 3 (100/150) would be an option worthwhile to be investigated in a next cycle of on-farm experimentation. Lower levels of fertilizer application (with relatively high responses to N and other nutrients) are anyhow the reality in farmers' fields in these days of ever-increasing prices of fertilizer.

The yield adjustment factor of 25 % is based on the following three components. In this experiment the timing of fertilizer application was a non-experimental factor, which was, however, as said earlier, managed by the researchers in order to avoid confounding of fertilizer level and timing of application effects. An additional practical reason is that the TAs had to make appointments (and fix a date) with the farmers for the application of the various quantities of fertilizer. Previous household-monitoring and trial results indicate that farmers apply in general 2 weeks too late which gives a decrease in yield of about 11 %. Secondly, the harvesting areas were quite small which contributes another 5 % to the yield adjustment factor. Thirdly, crop husbandry components such as the use of fresh hybrid seed (provided by the scientists), spacing and weeding might be better in on-farm experiments than in most farmers' fields through the 'influence/guidance' of TAs and the self-selection of trial farmers. This accounts for another 10 %, which makes the total about 25 %.

If one would do a partial budget analysis on the *mean* yield levels of the 4 treatments as given in table 10 (which should not be done because of the significant location x top interaction effect), then the following MRR would ensue.

Table 11: Marginal Rate of Returns based on means of treatments

Treatment	Fertilizer level	MRR-1	MRR-2
3	100/150		
1	150/150	41 %	6 %
2	100/200	dominated	dominated
4	150/200	119 %	64 %

MRR-1 is based on a field price of maize = ZKW 6500/bag and a yield adjustment factor of 15 %, while MRR-2 is based on a field price of ZKW 5500/bag and a yield adjustment factor of 25 %.

Treatment 2 is a dominated treatment (it has higher costs that vary but lower net benefits). In the column with the MRR-1 treatment 1 is eliminated from consideration because the MRR of 41 % is below the minimum rate of return of 90 %. When we calculate the MRR between treatment 3 and 4 it is 82 %, which is just below the minimum rate of return. With a lower field price for maize and a higher yield adjustment factor both the MRR are below the minimum acceptable value (see column MRR-2). This means that in the most optimistic case one could have come close to recommending treatment 4 - the treatment with the highest fertilizer levels which in only 2 out of 7 cases gave a higher yield than the other treatments (see graph 1). In the more pessimistic (and realistic) scenario one would stick to treatment 3, the treatment with the lower levels of basal and topdressing.

This shows that with a partial budget analysis based on mean values across farmers, and without a statistical analysis, one can end up selecting the wrong treatments for further research and eventually make incorrect recommendations to farmers.

Farmer assessment

Individual farmer assessments, which were part of the research protocols to be completed by the TAs, and comments received from farmers and extensionists during fielddays, indicate that little differences could be observed between the various treatments. This shows that on small plots it is difficult to observe with the naked eye differences between treatments which differ little in total quantity of fertilizer applied; however, the yield results show that significant differences do occur (the range from the lowest to the highest yielding plot was 2.8 to 8.1 ton/ha).

The general opinion of the trial farmers in a group assessment exercise was that the differences between the various treatments were not very large. At the presentation of the graphs depicting the interactions location x basal and location x top they acknowledged, however, that substantial differences between farmers do occur. According to the farmers the unexplained interaction location x topdressing can be due to differences in crop husbandry practices and/or localized rainfall patterns. As said earlier, the crop husbandry practices at each farm were registered but did not account for above interaction.

Final remarks

It is obvious that statistical analysis of the pooled results of on-farm experiments should precede the agronomic and economic analysis and the presentation of results to trial farmers. Researchers should be confident that there are real differences among treatments before embarking upon economic analysis and farmer assessment exercises (CIMMYT 1988, p.21 & 60). When resource-poor farmers are the main target group of FSR programs, and these farmers usually adopt innovations in a stepwise fashion, it follows that most experimental variables in on-farm trials should represent small steps. This in turn implies that in most cases only relatively small differences in yield between treatments will occur. Since variability among farms normally is high (this is the reason that we started on-farm experiments in the first place) these relatively small differences will get lost in the calculation of averages across farms. A proper statistical analysis across farms will reveal farm x treatment interactions and in that way contribute to relevant recommendations to farmers.

Realistic extension messages, which acknowledge the location-specific character of farming in Eastern and Southern Africa, cannot be developed without thorough analysis of on-farm experiments. Sound statistical, agronomic and economic analysis of on-farm experiments is a prerequisite to reliable, practical recommendations for farmers.

In order to improve the linkage between FSR teams and on-station researchers the credibility of on-farm research in the eyes of on-station scientists should be further enhanced. Also this calls for careful planning and implementation, thorough analysis, and adequate presentation of results of on-farm experiments. This might as well enhance the credibility of on-farm research in the eyes of other stakeholders in the agricultural development process.

Literature

CIMMYT; 1988
From agronomic data to farmer recommendations: an economics training manual. Completely revised edition. Mexico, D.F.

Eijk A.M. van; 1995
The use of K-values in MSTAT. FSRT-WP, Mongu, Zambia

Neeley D., J. Matata, F. Kisyombe; 1991
Statistical techniques for the analysis of on-farm crop trials. A manual. CIMMYT.

The CIMMYT manuals are available free of charge at:
CIMMYT Southern Africa Regional Office. PO Box MP 154, Mount Pleasant, Harare, Zimbabwe and
CIMMYT Eastern Africa Regional Office. PO Box 25171, Nairobi, Kenya.

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Graph 1

Graph 2 and 3