ICARDA / IFAD NILE VALLEY PROJECT

# ECONOMIC ANALYSIS AND IMPLICATIONS OF ON-FARM TRIALS, MINYA, EGYPT

## 1979/80 CROPPING SEASON

International Center for Agricultural Research in the Dry Areas

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ICARDA/IFAD NILE VALLEY PROJECT ON FABA BEANS

# ECONOMIC ANALYSES AND IMPLICATIONS OF ON-FARM TRIALS, MINYA, EGYPT

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by

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The International Center for Agricultural Research in the Dry Areas
(ICARDA)

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# PREFACE

This paper presents an economic analysis, and a discussion of the implications, of on-farm trials conducted in Minya Province, Egypt in 1979/80.

Agronomic results from these trials are discussed in Nasseib, et al.. A study of farm level constraints to high yield of faba beans in Minya Province. ICARDA/IFAD Nile Valley Project, Cairo, 1980.

The economic analysis presented here uses data collected in the agro-economic survey conducted in the Province during 1979/80, the results of which are presented in Salkini, et al.: Results of the agro-economic survey of faba bean production in Mynia Governorate, Egypt, 1979/80. ICARDA, Aleppo, 1983.

The analysis was carried out, and the paper written, by Abdul Bari Salkini. The work was guided throughout by David Nygaard. Acknowledgements are due to Elizabeth Bailey for the editing of earlier drafts; Abdel Rahman Hawa for artistic work; and Marica Boyagi and Katia Artinian for typing the many drafts.

CONTENTS

## INTRODUCTION

The Nile Valley Project (NVP) for improving faba bean production in Egypt and Sudan is one of ICARDA's major collaborative projects. It is funded by the International Fund for Agricultural Development (IFAD), administered, coordinated and scientifically supervised by ICARDA, and executed by national research institutes of the two countries.

Initiated in 1979, the project directed most of its resources to research activities, of which a considerable part was conducted on farmers' fields in order to identify major yield constraints, and to develop appropriate solutions. More extension activities are included in the Project's second phase which started in 1983.

This paper presents an economic analysis, a discussion of the implications, of agronomy trials conducted on farmers' fields in Minya Province, Egypt, during the 1979/80 cropping season. Minya Province (in middle Egypt) is the leading faba bean producing area in Egypt. It contributes about 30 percent of the country's total bean area and production. The crop covers 24 percent of the Province's total winter crop area, and is considered as one of the major cash crops contributing to the farming households' income. For these, and other, reasons the first season's research by the NVP was exclusively conducted in Minya.

As only one year's data are analysed in this paper, the conclusions and recommendations should be viewed cautiously. They should be considered as simply indications rather than firm, or precise, final findings. Valid conclusions and recommendations will become available only through the analyses of, at least, three years data.

# I. AGRONOMIC TRIALS[1/]

## 1. Methodology and objectives

An integrated experiment-survey research approach, as developed by de Datta, et al., (1978) on Asian rice farms, was followed when designing the agronomy trials in Minya.

Based on the findings of a preliminary farm survey of faba bean production, 26 sites (16 in Abou Kurkas district and 19 in Samaloot) were chosen on which to conduct on-farm trials. These sites represent different environmental conditions, holding size, tenure arrangements, and farmers' practices,(tillage system, irrigation regime, fertilizer application, rotations etc.).

Three pre-determined factors, thought to be the main factors contributing to a yield gap, were tested at two input levels: (1) the recommended, or high input level, and (2) the farmer's, or low input level. The latter which varied from farm to farm was determined by the farmer himself in the experimental plots, and was only monitored and recorded by researchers. The three tested factors and their levels of input are presented in Table 1. Other cultural practices such as tillage, watering management, weeding, etc., were considered as fixed factors and kept at farmers' levels.

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1/ Most of the basic agronomic data are cited from: Nasseib, et al., (1980).

Table 1. Recommended and farmers' levels of tested inputs.

| Factor | Recommended level | Farmers' levels |
|---|---|---|
| Variety | Giza 4 | Giza 2 |
| Plant population (plant/m²) | 41.7 | varied (10.7- 25.8) |
| Fertilizer - $P_2O_5$ (kg/ha) | 71.4 | varied ( 0-121.4) |
| - N (kg/ha) | 35.7 | varied ( 0-133.0) |

The main objectives of the trials are to:

1. test the performance of the three tested factors under different environments and farmers' practices, identify yield gaps, and measure the individual contribution of each factor to the gap, as well as the interactions between factors;
2. provide feed-back to researchers that helps in developing future research plans, design, and methodology; and
3. serve extension and demonstrative purposes, especially at the advanced stage of the on-farm research.

## 2. Agronomic results

Yield response to the recommended and farmers' levels of tested inputs varied widely across the sites:

1. On 12 sites the seed yield of the recommended inputs treatment surpassed the yields of the farmers' inputs treatment (mean yields were 3.047 and 2.156 ton/ha respectively). The two treatments yielded almost the same on four sites, while farmers' practices gave higher yields than the recommended practices on seven sites (averages were 3.360 and 2.657 ton/ha respectively).

However, across all sites, the average yield from the recommended treatments exceeded that from the farmers' level of inputs by 0.329 ton/ha of grain and 1.218 ton/ha of straw.

2. For economic analysis purposes, data from 12 sites, where the farmers' level of inputs, particularly fertilizer, are lower than the recommended level, have been analysed separately, and significant yield increases of 0.518 ton/ha of seed and 1.368 ton/ha of straw were produced by the recommended level of inputs.

3. In the complete factorial trials, conducted on six sites, yield increases due to recommended fertilizer alone were 0.259 ton/ha of seed, and 1.100 ton/ha of straw. Corresponding figures for the recommended plant population were 0.214 ton/ha, and 1.400 ton/ha, and for the combined factors 0.319 ton/ha and 1.92 ton/ha, of seed and straw respectively.

4. In order to emphasize the role of the recommended rates of fertilizer alone in increasing yields and net benefits, data from three sites where the farmers' level of fertilizer was very low were analysed. The yield increase due to the recommended rate of fertilizer was 0.400 ton/ha of seed and 1.223 ton/ha of straw.

# II. ECONOMIC RESULTS

## 1. Hypotheses

Major workig hypotheses for the economic analysis of the agronomy trials are:

1. Farmers are mostly more concerned with profit maximization than with a simple physical yield increase; farmers, especiall small farmers, are risk averse. Therefore, it is expected that farmers may adopt new production recommendations that are more profitable, and that do not involve a greater risk than the practices they are already using.

2. Different treatments with different physical yields produce different economic benefits. This is due to variations in input costs and output values of the different treatments.

3. Physically higher yielding treatments are not necessarily the best bet economically; there could be treatments with a lower physical yield but with a higher economic benefit.

## 2. Objectives and methodology

A partial budgeting technique is used to evaluate, economically, the different treatment combinations of the on-farm trials, i.e., to calculate benefits gained and costs incurred due to the adoption of improved technological components, and practices. From this the best alternative treatment in terms of cash income, profitability, and capital use efficiency under different farmers' situations can be identified.

No sophisticated training is needed to draw up budgets of alternative production packages (Nordblom et al., 1983). The purpose of partial budgeting is to organize information in such a way as to help make a particular decision (Perrin et al., 1976). Basic data needed to accomplish the analysis are:

Gross benefit: Net yield multiplied by field price,

Variable cost: The sum of the cost of the inputs involed in adopting one trial treatment as opposed to another,

Net benefit: Gross benefit minus variable cost.[1/]

## 3. Economic results and their implications

Several partial budgets for several experiments are calculated and analysed in order to identify the economic implications of the different treatment combinations of the tested inputs.

Firstly, partial budgets have been calculated for the trials conducted on 23 sites where two treatment combinations are tested. These are:

(1) the recommended or high level inputs (Tr), and
(2) the farmer, or low level inputs (Tf).

These partial budgets aim to find the economic merits of the three tested factors together across all sites.

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1/ Information on input costs and product prices were obtained from the agro-economic survey in Minya Province (Salkini, et al., 1983).

Table 2. Partial budgets of tested inputs on 23 sites for farmers' levels (Tf) vs. recommended levels (Tr). 1/

| | | Tr | Tf | Tr-Tf | % increase of Tr over Tf |
|---|---|---|---|---|---|
| Grain yield | ton/ha | 3.103 | 2.774 | 0.329 | 11.8 |
| Straw yield | ton/ha | 6.863 | 5.645 | 1.218 | 21.6 |
| Gross benefits | LE/ha | 771.3 | 677.8 | 93.5 | 13.8 |
| Total variable costs | LE/ha | 114.1 | 71.5 | 42.6 | 59.6 |
| Net benefit | LE/ha | 657.2 | 606.3 | 50.9 | 8.4 |

1/ See Appendix I and II for more details.

It is shown in Table 2 that (1) the recommended level of tested inputs (Tr) yielded an increase of 11.8 percent of grain and 21.6 percent of straw over the yields from farmers' levels of inputs (Tf); (2) net benefit increased by 8.4 percent and the rate of return (for additional cost incurred due to adoption of recommended level of inputs) equals 119 percent. This rate of return is certainly an attractive one.

Secondly, since a considerable proportion of the sample farmers are already using a high level of inputs (particularly fertilizer), partial budgets for 12 sites, where farmers used a lower level of fertilizer and plant population than recommended are presented in Table 3. These budgets are calculated in order to find how much these farmers would benefit if they adopted higher levels of inputs. Data in Table 3 show that farmers may realize a net benefit increase of 78.4 LE/ha, and a rate of return of 141 percent. The corresponding figures for the whole sample as shown in Table 2 are 50.9 LE/ha and 119 percent.

Table 3. Partial budgets for 12 sites where farmers' levels of inputs are lower than recommended.

| | | Treatment with tested inputs at farmer level (1) | Treatments with tested inputs at recommended level (2) | (2)-(1) |
|---|---|---|---|---|
| Grain yield | ton/ha | 2.397 | 2.915 | 0.518 |
| Straw yield | ton/ha | 5.900 | 7.268 | 1.368 |
| Gross benefit | LE/ha | 610.2 | 744.3 | 134.1 |
| Total variable cost | LE/ha | 58.5 | 114.1 | 55.5 |
| Net benefit | LE/ha | 551.6 | 630.2 | 78.4 |

See Appendix III and IV.

Thirdly, the analysis is extended to include the complete factorial trials (Table 4 and Figure 1). The objective of these trials is to determine the individual contribution and interactions of the three tested factors. The trials contain the following four treatment combinations.

T1 - all tested factors at farmers' level
T2 - all tested factors at recommended level
T3 - only plant population at recommended level
T4 - only fertilizer at recommended level

Table 4. Partial budgets for the complete factorial trials.

| | | T1 | T2 | T3 | T4 |
|---|---|---|---|---|---|
| Grain yield | ton/ha | 2.698 | 3.017 | 2.912 | 2.957 |
| Straw yield | ton/ha | 4.450 | 6.370 | 5.850 | 5.550 |
| Gross benefits | LE/ha | 634.3 | 742.7 | 709.7 | 711.2 |
| Variable costs | LE/ha | 76.0 | 114.0 | 112.5 | 77.5 |
| Net benefits | LE/ha | 558.3 | 628.7 | 597.2 | 633.7 |

See Appendix V and VI.

Table 4 and the net benefit curve in Figure 1 reveal the following findings:

1. The physically higher yielding treatment (T2) is not necessarily the best bet economically; T4 (only fertilizer at recommended level) requires a very small increment in cost (LE 1.5) over T1 (farmers' level of input) while it creates a considerable increase in net benefit (LE 75.4), and a 5026 percent marginal rate of return, as demonstrated by the steepness of the slope.

2. T2 (all tested factors at recommended level) and T3 (only plant population at recommended level) are dominated alternatives, i.e., there is another alternative, T4, with lower variable costs and a higher net benefit.

3. Although researchers believe that a high plant population has a considerable effect on yield, the economic analysis reveals that this is not reflected in an economic benefit; therefore, this factor requires more investigation in order to obtain a more precise indication of the biological, as well as the economic, impact of high seed rates on yield and net benefit.

Fourth, in order to avoid misleading conclusions it must be explained that the exceptionally high economic return of the recommended level of fertilizer application discussed above (T4, Table 4) is due to the fact that, while all the sample farmers use fertilizer, (1) many farmers used fertilizer at levels higher than the recommended level, and (2) rates and combinations of $P_2O_5$ and N varied widely. Therefore, conducting the analysis using the averages of the whole sample gave an exceptional economic return to a more rational fertilizer application. This, of course, is a misleading finding. To estimate a more realistic economic return to fertilizer application, partial budgets for three sites where the farmers' levels of

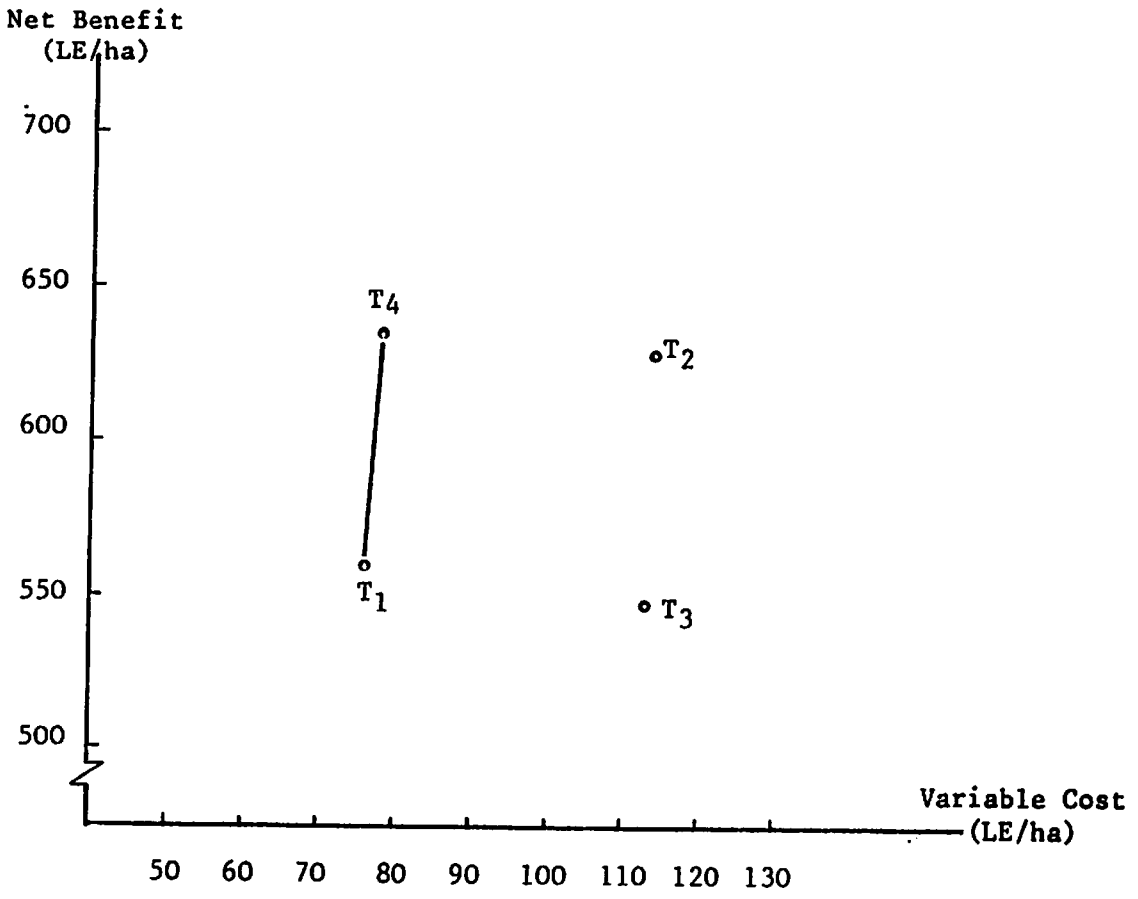


FIGURE 1 NET BENEFIT CURVE OF THE COMPLETE FACTORIAL TREATMENTS

$T_1$ : All tested factors at farmer level

$T_2$ : All tested factors at recommended level

$T_3$ : Only plant population at recommended level

$T_4$ : Only fertilizer at recommended level

fertilizer was lower than that recommended were calculated (Table 5). One farmer used 35.7 kg/ha $P_2O_5$, while the other two used 15.5 kg/ha and 42.8 kg/ha of N alone). Recommended rates are 71.4 kg/ha of $P_2O_5$ and 35.7 kg/ha of N.

Table 5. Partial budgets for 3 sites with farmers' levels of fertilizer lower than recommended.

| | Treatment with test factors at farmer level (1) | Treatments with only fertilizer at recommended level (2) | (2)-(1) |
|---|---|---|---|
| Grain yield ton/ha | 2.015 | 2.415 | 0.400 |
| Straw yield ton/ha | 3.837 | 5.060 | 1.223 |
| Gross benefit LE/ha | 486.0 | 593.6 | 107.5 |
| Total variable cost LE/ha | 5.9 | 23.6 | 17.7 |
| Net benefit LE/ha | 480.2 | 570.0 | 89.8 |

See Appendix VII and VIII

The adoption of the recommended rates of fertilizer by farmers who apply very low rates may produce an increase of LE 89.8/ha in net benefit while requiring only LE 17.7/ha additional expenditure. With a marginal rate of return of 507 percent, this is a very attractive investment.

## CONCLUSIONS

A package of recommended new variety, plant population of 41 plant/m², and fertilizer rates of 71.4 kg/ha $P_2O_5$ and 35.7 kg/ha N, proved to be economically feasible as it may create an extra net benefit of 61 LE/ha. However, under capital scarce conditions, farmers can adopt the recommended level of fertilizer alone as this does not require much increase in expenditure since farmers already apply fertilizer to their crop. Adopting the recommended rate of fertilizer would mean, for most farmers, either rationalizing their current expenditure on fertilizer, or adding some additional quantities of either $P_2O_5$, N, or both.

More breeding research is required in order to develop a variety with a potential yield higher than Giza 4 (already recommended), which has proved not to be significantly better than the farmers' variety, Giza 2.

Further research is also required to assess optimal seeding rates, both in physical and economic terms. Many plots seeded at the farmers' rates, whose plant populations tend to be much lower than the recommended level, yielded the same as, or even more than, densely populated plots.

## REFERENCES

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# APPENDICES

APPENDIX I Partial budgets of average yield data from 23 sites of the on-farm Trials

| | | Farmer level of test inputs (Tf) | Recommended level of test inputs (Tr) |
|---|---|---|---|
| **BENEFITS** | | | |
| Grain yield | ton/ha | 2.774 | 3.103 |
| straw yield | ton/ha | 5.645 | 6.863 |
| grain price | LE/ton | 195.5 | 195.5 |
| straw price | LE/ton | 24.0 | 24.0 |
| grain benefit | LE/ha | 542.3 | 606.6 |
| straw benefit | LE/ha | 135.5 | 167.7 |
| GROSS BENEFIT | LE/ha | 677.8 | 771.3 |
| **VARIABLE COSTS** | | | |
| Amount of $P_2O_5$ provided by the bank | kg/ha | 55.8 | 55.8 |
| Amount of $P_2O_5$ provided by the market | kg/ha | 5.4 | 15.6 |
| Bank price of 1 kg of $P_2O_5$ | LE/kg | 0.19 | 0.19 |
| Market price of 1 kg of $P_2O_5$ | LE/kg | 0.33 | 0.33 |
| Cost of $P_2O_5$ provided by the bank | LE/ha | 10.6 | 10.6 |
| Cost of $P_2O_5$ provided by the market | LE/ha | 1.79 | 5.15 |
| (1) total costs of $P_2O_5$ | LE/ha | 12.39 | 15.75 |
| Amount of N provided by the bank | kg/ha | 27.9 | 27.9 |
| Amount of N provided by the market | kg/ha | 24.4 | 7.8 |
| Bank price of 1 kg of N | LE/kg | 0.15 | 0.15 |
| Market price of 1 kg of N | LE/kg | 0.215 | 0.215 |
| Cost of N provided by the bank | LE/ha | 4.185 | 4.185 |
| Cost of N provided by the market | LE/ha | 5.245 | 1.675 |
| (2) total costs of N | LE/ha | 9.43 | 5.86 |
| (3) labor cost of fertilizer application | LE/ha | 1.7 | 2.0 |
| Seeding rate | kg/ha | 165.0 | 335.0 |
| Seed price | LE/kg | 0.21 | 0.21 |
| (4) cost of seeds | LE/ha | 34.65 | 70.50 |
| (5) labor costs of seeding | LE/ha | 13.33 | 20.00 |
| TOTAL VARIABLE COSTS | LE/ha | 71.5 | 114.11 |
| NET BENEFIT | LE/ha | 606.3 | 657.2 |

APPENDIX II Grain and straw yields of farmers' and recommended levels of tested factors, on individual trial sites

| Site No. | Grain yield (ton/ha) | | Straw yield (ton/ha) | | Farmers' level of tested inputs | | |
|---|---|---|---|---|---|---|---|
| | Recommended | Farmer | Recommended | Farmer | $P_2O_5$ | N | Plant population plant/m² |
| 1 | 2.857 | 2.363 | 7.093 | 4.122 | 35.7 | 0 | 10.8 |
| 2 | 3.457 | 2.592 | 7.433 | 4.594 | 0.0 | 15.5 | 17.8 |
| 3 | 2.764 | 3.606 | 6.443 | 6.244 | 92.9 | 105.9 | 21.8 |
| 4 | 2.204 | 1.092 | 5.737 | 2.794 | 0.0 | 42.8 | 18.5 |
| 5 | 4.061 | 3.991 | 6.345 | 4.650 | 37.4 | 105.5 | 19.3 |
| 6 | 2.759 | 2.549 | 5.169 | 4.303 | 114.3 | 104.8 | 24.3 |
| 8 | 2.116 | 1.949 | 5.124 | 4.831 | 71.4 | 0.0 | 15.6 |
| 9 | 4.055 | 4.004 | 8.974 | 7.390 | 65.5 | 133.0 | 10.7 |
| 10 | 3.148 | 3.316 | 7.349 | 7.437 | 0.0 | 57.0 | 13.8 |
| 11 | 3.751 | 3.980 | 7.258 | 6.222 | 86.2 | 91.9 | 18.5 |
| 12 | 3.574 | 2.693 | 6.389 | 4.233 | 121.4 | 47.6 | 15.7 |
| 13 | 3.320 | 3.364 | 6.432 | 5.416 | 81.0 | 49.7 | 25.8 |
| 14 | 3.376 | 2.941 | 5.257 | 4.192 | 0.0 | 101.9 | 19.5 |
| 15 | 2.208 | 1.117 | 12.470 | 5.842 | 71.4 | 0.0 | 17.5 |
| 16 | 2.688 | 2.983 | 9.219 | 7.517 | 42.5 | 14.3 | 13.5 |
| 17 | 3.088 | 3.054 | 5.002 | 5.696 | 53.6 | 23.6 | 13.7 |
| 18 | 4.181 | 1.227 | 6.087 | 1.455 | 71.4 | 73.8 | 13.9 |
| 19 | 2.683 | 2.300 | 6.401 | 6.898 | 71.4 | 21.5 | 14.3 |
| 20 | 2.425 | 2.787 | 4.843 | 6.087 | 89.3 | 36.9 | 15.5 |
| 21 | 3.397 | 2.624 | 9.238 | 9.267 | 107.1 | 0.0 | 14.3 |
| 22 | 3.753 | 2.429 | 6.791 | 7.601 | 53.6 | 34.8 | 25.7 |
| 25 | 3.828 | 4.185 | 9.566 | 9.889 | 71.4 | 36.9 | 15.7 |
| 26 | 1.675 | 2.662 | 3.228 | 3.171 | 71.4 | 54.8 | 19.7 |
| $\bar{X}$ | 3.103 | 2.774 | 6.863 | 5.645 | 61.2 | 52.3 | 17.2 |

Recommended level of fertilizer kg 71.4 of $P_2O_5$ - 35.7 of N per hectare.
Recommended plant population 41.7 plant/$m^2$.

APPENDIX III Partial budgets of average yields from 12 sites where Tf of fertilizer and plant population is less than Tr recommended

| | | Farmer level of test inputs | Recommended level of test inputs |
|---|---|---|---|
| **BENEFITS** | | | |
| Grain yield | ton/ha | 2.397 | 2.915 |
| Straw yield | ton/ha | 5.900 | 7.268 |
| Grain benefit | LE/ha | 468.600 | 569.900 |
| Straw benefit | LE/ha | 141.600 | 174.400 |
| Gross benefit | LE/ha | 610.200 | 744.300 |
| **VARIABLE COSTS** | | | |
| Amount of $P_2O_5$ provided by bank | kg/ha | 40.7 | 55.8 |
| Amount of $P_2O_5$ provided by market | kg/ha | 0.0 | 15.6 |
| Cost of $P_2O_5$ provided by bank | LE/ha | 7.730 | 10.600 |
| Cost of $P_2O_5$ provided by market | LE/ha | 0.00 | 5.150 |
| (1) total costs of $P_2O_5$ | LE/ha | 7.730 | 15.750 |
| Amount of N provided by bank | kg/ha | 25.9 | 27.9 |
| Amount of N provided by market | kg/ha | 0.0 | 7.8 |
| Cost of N provided by bank | LE/ha | 3.885 | 4.185 |
| Cost of N provided by market | LE/ha | 0.00 | 1.675 |
| (2) total cost of N | LE/ha | 3.885 | 5.860 |
| (3) labor cost of fertilizer application | LE/ha | 1.000 | 2.000 |
| Seeding rate | kg/ha | 156 | 335 |
| (4) costs of seeds | LE/ha | 32.760 | 70.500 |
| (5) labor costs of seeding | LE/ha | 13.200 | 20.000 |
| TOTAL VARIABLE COSTS | LE/ha | 58.575 | 114.110 |
| NET BENEFIT | LE/ha | 551.625 | 630.190 |

Remark: Prices are presented in preceding tables.

APPENDIX IV Grain and straw yield on 12 sites where Tf of fertilizer and plant population is less than Tr

| Site No. | Grain yield (ton/ha) | | Straw yield (ton/ha) | | Farmers' level of tested inputs | | |
|---|---|---|---|---|---|---|---|
| | Recommended | Farmer | Recommended | Farmer | $P_2O_5$ | N | Plant population plant/m² |
| 1 | 2.857 | 2.363 | 7.093 | 4.122 | 35.7 | 0 | 10.8 |
| 2 | 3.457 | 2.592 | 7.433 | 4.594 | 0.0 | 15.5 | 17.8 |
| 4 | 2.204 | 1.092 | 5.737 | 2.794 | 0.0 | 42.8 | 18.5 |
| 8 | 2.116 | 1.949 | 5.124 | 4.831 | 71.4 | 0.0 | 15.6 |
| 10 | 3.148 | 3.316 | 7.349 | 7.437 | 0.0 | 57.0 | 13.8 |
| 14 | 3.376 | 2.941 | 5.257 | 4.192 | 0.0 | 101.9 | 19.5 |
| 15 | 2.208 | 1.117 | 12.470 | 5.842 | 71.4 | 0.0 | 17.5 |
| 16 | 2.688 | 2.983 | 9.219 | 7.517 | 42.5 | 14.3 | 13.5 |
| 17 | 3.088 | 3.054 | 5.002 | 5.696 | 53.6 | 23.6 | 13.7 |
| 19 | 2.683 | 2.300 | 6.401 | 6.898 | 71.4 | 21.5 | 14.3 |
| 21 | 3.397 | 2.624 | 9.238 | 9.267 | 107.1 | 0.0 | 14.3 |
| 22 | 3.753 | 2.429 | 6.791 | 7.601 | 53.6 | 34.8 | 25.7 |
| $\bar{X}$ | 2.915 | 2.397 | 7.268 | 5.900 | 40.7 | 25.9 | 16.3 |

APPENDIX V Partial budget of average yields for factorial trials at six sites

| | | T1* | T2 | T3 | T4 |
|---|---|---|---|---|---|
| **BENEFIT** | | | | | |
| Grain yield | ton/ha | 2.698 | 3.017 | 2.912 | 2.957 |
| Straw yield | ton/ha | 4.450 | 6.370 | 5.850 | 5.550 |
| Grain price | LE/ton | 195.5 | 195.5 | 195.5 | 195.5 |
| Straw price | LE/ton | 24 | 24 | 24 | 24 |
| Grain benefit | LE/ha | 527.460 | 589.820 | 569.300 | 578.000 |
| Straw benefit | LE/ha | 106.800 | 152.800 | 140.400 | 133.200 |
| TOTAL BENEFIT | LE/ha | 634.260 | 742.700 | 709.700 | 711.200 |
| **VARIABLE COSTS** | | | | | |
| Amount of $P_2O_5$ provided by the bank | kg/ha | 46.7 | 55.8 | 46.7 | 55.8 |
| Amount of $P_2O_5$ provided by the market | kg/ha | - | 15.6 | - | 15.6 |
| Cost of $P_2O_5$ provided by bank | LE/ha | 8.870 | 10.600 | 8.870 | 10.600 |
| Cost of $P_2O_5$ provided by market | LE/ha | - | 5.150 | - | 5.150 |
| (1) total costs of $P_2O_5$ | LE/ha | 8.870 | 15.750 | 8.870 | 15.750 |
| Amount of N provided by the bank | kg/ha | 27.9 | 27.9 | 27.9 | 27.9 |
| Amount of N provided by the market | kg/ha | 34.5 | 7.8 | 34.5 | 7.8 |
| Cost of N provided by the bank | LE/ha | 4.185 | 4.185 | 4.185 | 4.185 |
| Cost of N provided by the market | LE/ha | 7.413 | 1.675 | 7.415 | 1.675 |
| (2) total costs of N | LE/ha | 11.600 | 5.860 | 11.600 | 5.860 |
| (3) labor cost of fertilizer | LE/ha | 1.700 | 2.100 | 1.700 | 2.100 |
| Total costs of fertilizer | LE/ha | 22.170 | 23.710 | 22.170 | 23.710 |
| Seeding rate | kg/ha | 185 | 335 | 335 | 185 |
| (4) cost of seed | LE/ha | 38.850 | 70.350 | 70.350 | 38.840 |
| (5) labor cost of seeding | LE/ha | 15.000 | 20.000 | 20.000 | 15.000 |
| Total cost of seed and seeding | LE/ha | 53.850 | 90.350 | 90.350 | 53.850 |
| TOTAL VARIABLE COSTS | LE/ha | 76.000 | 114.000 | 112.520 | 77.560 |
| NET BENEFITS | LE/ha | 558.260 | 628.700 | 597.180 | 633.640 |

* T1 - all tested factors at farmer level
T2 - all tested factors at recommended level
T3 - plant population only at recommended level
T4 - fertilizer only at recommended level

Bank price of $P_2O_5$ = 0.19 LE/kg
Bank price of N = 0.15 LE/kg
Seed price = 0.215 LE/kg
Market price of $P_2O_5$ = 0.33 LE/kg
Market price of N = 0.215 LE/kg

APPENDIX VI Grain and straw yields of the six sites of the complete factorial trials; farmers' level and recommended level of one or more tested factors. (ton/ha)

| Site No. | GRAIN YIELDS F | R | Plant population only at R. | Fertilizer only at R. | Farmers' level of tested inputs $P_2O_5$ (kg) | N (kg) | Plant population plant/m² |
|---|---|---|---|---|---|---|---|
| 1 | 2.363 | 2.857 | 2.461 | 2.230 | 35.7 | 0 | 10.8 |
| 2 | 2.592 | 3.457 | 2.611 | 2.925 | 0.0 | 15.5 | 17.8 |
| 3 | 3.606 | 2.764 | 3.691 | 3.058 | 92.9 | 105.9 | 21.8 |
| 4 | 1.092 | 2.204 | 1.772 | 2.090 | 0.0 | 42.8 | 18.5 |
| 5 | 3.991 | 4.061 | 3.967 | 4.568 | 37.4 | 105.5 | 19.3 |
| 6 | 2.549 | 2.759 | 2.971 | 2.871 | 114.3 | 104.8 | 24.3 |
| ΣX | 16.193 | 18.102 | 17.473 | 17.742 | 280.3 | 374.5 | 112.5 |
| $\bar{X}$ | 2.698 | 3.017 | 2.912 | 2.957 | 46.7 | 62.4 | 18.75 |
| | STRAW YIELDS | | | | | | |
| 1 | 4.122 | 7.093 | 6.209 | 4.764 | - | - | - |
| 2 | 4.594 | 7.433 | 6.334 | 4.952 | - | - | - |
| 3 | 6.244 | 6.443 | 7.836 | 6.988 | - | - | - |
| 4 | 2.794 | 5.737 | 4.288 | 5.465 | - | - | - |
| 5 | 4.650 | 6.345 | 5.462 | 6.388 | - | - | - |
| 6 | 4.303 | 5.169 | 4.982 | 4.745 | - | - | - |
| ΣX | 26.707 | 38.220 | 35.111 | 33.302 | - | - | - |
| $\bar{X}$ | 4.451 | 6.370 | 5.851 | 5.551 | - | - | - |

APPENDIX VII Partial budgets of average yield data from three sites where Tf of fertilizer is less than Tr

| | | Farmers level of test inputs | Fertilizer only as recommended |
|---|---|---|---|
| **BENEFITS** | | | |
| Grain yield | ton/ha | 2.015 | 2.415 |
| Straw yield | ton/ha | 3.837 | 5.060 |
| Grain benefit | LE/ha | 393.930 | 472.130 |
| Straw benefit | LE/ha | 92.100 | 121.440 |
| Gross benefit | LE/ha | 486.030 | 593.570 |
| **VARIABLE COSTS** | | | |
| Amount of $P_2O_5$ provided by bank | kg/ha | 11.9 | 55.8 |
| Amount of $P_2O_5$ provided by market | kg/ha | 0.0 | 15.6 |
| Cost of $P_2O_5$ provided by bank | LE/ha | 2.260 | 10.600 |
| Cost of $P_2O_5$ provided by market | LE/ha | 0.0 | 5.150 |
| (1) total costs of $P_2O_5$ | LE/ha | 2.260 | 15.750 |
| Amount of N provided by bank | kg/ha | 19.4 | 27.9 |
| Amount of N provided by market | kg/ha | 0.0 | 7.8 |
| Cost of N provided by bank | LE/ha | 2.910 | 4.185 |
| Cost of N provided by market | LE/ha | 0.0 | 1.675 |
| (2) total cost of N | LE/ha | 2.910 | 5.860 |
| (3) labor cost of fertilization | LE/ha | 0.700 | 2.000 |
| TOTAL VARIABLE COSTS | LE/ha | 5.870 | 23.610 |
| NET BENEFITS | LE/ha | 480.160 | 569.960 |

APPENDIX VIII Grain and straw yields from three sites with Tf of fertilizer less than Tr

| Site No. | Grain yield (ton/ha) | | Straw yield (ton/ha) | | Farmer level of Fertlizer | |
|---|---|---|---|---|---|---|
| | Fertilizer | F. Level | Fertilizer | Fertilizer | $P_2O_5$ | N |
| 1 | 2.230 | 2.369 | 4.764 | 4.122 | 35.7 | 0.0 |
| 2 | 2.925 | 2.592 | 4.952 | 4.595 | 0.0 | 15.5 |
| 3 | 2.090 | 1.092 | 5.465 | 2.794 | 0.0 | 42.8 |
| $\bar{X}$ | 2.415 | 2.015 | 5.060 | 3.837 | 11.9 | 19.4 |