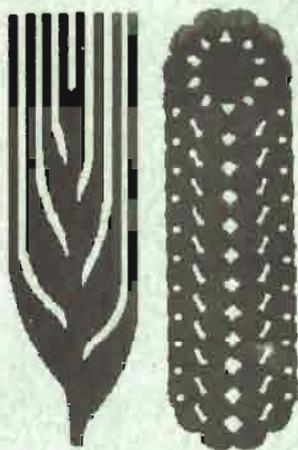


**RESULTS OF CIMMYT'S REGIONAL MAIZE
AGRONOMY TRIAL NETWORK ACROSS
CENTRAL AMERICA AND THE CARIBBEAN**

English Executive Summary, 1990
Guatemala, July 1991



**Resultados Preliminares de
Investigación para Discusión
Interna Dentro del Programa
Regional**

**Programa Regional de CIMMYT para Centro
América y El Caribe**

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RESULTS OF CIMMYT'S REGIONAL MAIZE AGRONOMY TRIAL NETWORK ACROSS CENTRAL AMERICA AND THE CARIBBEAN, 1990¹

H.J. Barreto, G.E. Sain, W.R. Raun and J.A. Bolaños²

Introduction

CIMMYT's collaborative Agronomic research in Central America and the Caribbean began in 1988 with the initiation of a series of similar trials across the region. Three types of trials were established: interseeding of legumes with maize, conservation tillage and fertilization with P and S. Despite the problems inherent to the initiation and maintenance of a collaborative research network involving 7 countries, and the high rate of staff turnover within the National Research institutions, in just two years of experimentation the project has already shown relevant research results which will aid in the formulation of more local adaptive research for countries in the region. It is essential to emphasize that the research results presented in this book belong to all National Agricultural Research Institutions that comprise the Regional Maize Program for Central America and the Caribbean.

Technical details regarding the different research projects can be found in the various documents produced by the Regional Program. The objective of this document is to provide an executive summary and highlight the most important achievements in the integrated activities of Agronomy and Economics. However, this document does not include all research activities by the Regional Program but only those that produced significant results during 1990.

In 1990, important results were achieved in the collaborative projects of Agronomy and Economics. These findings encompass a spectrum of topics including purely methodological issues arising from the need to compile and analyze data from uniform trials across multiple environments, as well as from the biological study of yield components in maize. In all these results, the integration between Agronomy and Economics has been emphasized.

¹ This document is an English version of the Introductory chapter of the publication, *Análisis de los Ensayos Regionales de Agronomía, 1990*, Programa Regional de Maíz para Centro América y el Caribe, published in June, 1991, by CIMMYT's Regional Office in Guatemala.

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Regional Agronomy Trials

Research on Legume Interseeding/Rotations

Field research on interseeding of legumes with maize produced fairly consistent results across the region. In 1989 and 1990, complete information was collected on 24 factorial-type trials each with 11-15 treatments replicated 3 times. These examined the impact of interseeding three legume species (*Canavalia ensiformis*, *Stizolobium deeringianum* and *Vigna unguiculata*) when planted around the same time than maize, in relation to the productivity of monocropped maize, and the potential for soil cover that the legume crop would offer for soil conservation. The objectives were to evaluate the impact of the legume intercrop on maize yields, the degree of soil cover and protection against erosion by the legume, and the residual effect of the legume for the next cycle of monocropped maize. The compiled data across both years for the effect on maize yield is presented in the paper by Zea et al. (p.27).

The main effect of interseeding a legume within a maize crop is a reduction in maize yield by direct competition for water, nutrients and radiation. Depending on the species, the impact of interseeding on maize yields differed in both magnitude and variability. However, the cost of adopting such technology for the farmer must include, in addition to the yield loss in terms of maize, the costs of planting and managing the legume. The following table illustrates the short term costs for adopting the practice of legume interseeding.

Table 1. Maize Yield Reduction and Economic Costs of Legume Interseeding.				
Legume Species	Yield reduction ton/ha	Value of reduction US\$/ha ¹	Planting and management costs US\$/ha ²	Total costs US\$/ha/yr
<i>Canavalia ensiformis</i>	0.32±0.45 ³	40.32±56.70	30.00	70.32±56.70
<i>Vigna unguiculata</i>	0.51±0.58	64.26±73.08	30.00	94.26±73.08
<i>Stizolobium deeringianum</i>	0.63±0.77	79.38±97.02	48.00	127.38±97.02

1/ Maize field price was assumed to be US\$126/ton.

2/ Do not include the price of the legume seed

3/ The number following ± represents the standard deviation of the sample (n=44)

However, the benefits of incorporating a legume crop into a monocropped maize system have both short and long term impacts. Some of the short term benefits include a reduction in the costs of weed control, the value of the grain and/or fodder produced by the legume crop, and the residual effect of additions of organic matter and fixed N. In the long term, by maintaining a semi-permanent soil cover, the legume intercrop would reduce soil erosion and aid in soil conservation. Although the information is still incomplete on these effects for the legume species evaluated, it is clear that to be of economic significance they should compensate at least for the annual costs mentioned.

Across all environments evaluated, *C.ensiformis* seemed preferable for early intercropping with maize because of its smaller maize yield reduction and its smaller associated variance (Table 1). In addition, preliminary results on the residual effect of these legume intercrops, suggest that both *C.ensiformis* and *S.deeringianum* can compensate for the yield loss during the first cycle because of addition of organic matter and fixed N which become available for the next cycle. This can mean savings in fertilizer use to the farmer. However, available information about the residual effect of the legume intercrop and associated nutrient recycling is still inadequate, and constitutes one of the focal points for research in a future phase of the project.

Interestingly, across the 24 environments evaluated ranging in yield from 1 to 6 ton/ha, the absolute reduction in yield brought on by the legume crop appeared independent of the yield potential, defined as the mean yield for all treatments in a given environment or location. However, it was expected that the yield loss would be greater in environments where water, nutrients or radiation were limiting. The lack of a discernable interaction between yield reduction by legume intercropping and yield potential constitutes an important argument in support of the feasibility of obtaining valuable agronomic information through similar series of regional trials, despite large variation in yield levels.

As the analysis of agronomic information generates useful results, socioeconomic studies have examined the possibilities for adoption of legume intercropping within the existing maize farming systems in the Central American and Caribbean region. One important aspect has been to document existing legume rotation/interseeding practices in the region. The paper by Buckles et al. (p.85) presents a survey of the use of *Mucuna* s. (*S.deeringianum*) as a green manure crop by farmers in the Atlantic Coast of Honduras.

Research on Phosphorus (P) and Sulphur (S)

Research on P and S fertilization focused mostly in soils derived from volcanic ash that often present P deficiency as well as high fixation capacity for applied P fertilizer. The regional trials attempted to establish maize yield responses throughout Central America to different P-sources (triple superphosphate, phosphate rock, and available formula fertilizers, e.g. 18-46-0), levels (0, 30, 60 and 90 kg P₂O₅/ha) and methods of application of P. Over 80% of the sites where trials were established were considered as P deficient (<10 ppm P by the Nelson method). Another objective was to identify relevant soil and environmental parameters which may determine in addition to soil testing, the probability of a yield response to applications of P. These results are presented in the paper by Gordón et al. (p.43).

During 1989 and 1990 data were obtained from 33 trials on P and S fertilization across the region. Triple superphosphate (TSP) was the P-source which presented the most consistent response across the region, therefore it was used to characterize the

mean response across the region. In 1989, the mean yield response to 30 and 60 kg P_2O_5 /ha across 17 trials was 0.54 ± 0.89 and 0.84 ± 0.91 ton/ha, respectively. For 1990, the mean response across 16 trials to the same source and doses was 0.21 ± 0.54 and 0.53 ± 0.54 ton/ha. The legume interseeding trials of 1990 (13 trials) included treatments designed to evaluate the response to P of monocropped maize. Data indicated that application of 46 and 92 kg P_2O_5 /ha resulted in yield responses of 0.30 ± 0.43 and 0.60 ± 0.47 ton/ha. As in the legume interseeding trials, the yield increase due to P application appeared independent of the yield potential of the environment, that is, its magnitude was unrelated to the average grain yield per location which ranged from 1.0 to 7.0 ton/ha.

Response to P applications as Rock Phosphate did not measure up to the response found for TSP or formula grade fertilizers. On the average of 7 trials the efficiency of Rock Phosphate during the application cycle was less than 60% of that found for TSP or formula. In addition, preliminary results show little residual fertilizer effect of the different P sources on the following maize crop. Mean yield gain during the residual cycle as affected by P sources averaged over sources, doses and methods was 0.33 ± 0.12 ton/ha, with little or no differences among sources or rates. At the regional level, even in the case of TSP, the rather modest yield increase caused by fertilization during the application cycle (14-18 kg grain/kg P_2O_5), the low level of residuality for the following cycle (5.5-11 kg grain/kg P_2O_5) and low overall mean yields for regional experimentation (<4.0 ton/ha), suggest that overall maize crop utilization efficiency of fertilizer P is very low. The paper presented by Fuentes et al. (p.63) summarizes preliminary findings on residual effects of P fertilizers.

Several correlations were found between the magnitude of the response to P as TSP and soil parameters across all locations. For example, most of the positive responses to P fertilization occurred in soils with organic matter contents below 2.5%, soil pH less than 6.5, and soil extractable P below 10 ppm (Nelson method). However, due to the dispersion of the data, it was impossible to establish a general relationship at the regional level.

Based on current average prices for the region, 6 kg of maize grain are needed to buy 1 kg of P_2O_5 as TSP. Using this price ratio, it takes a minimum yield response of 180, 360 and 540 kg maize grain to pay for the additions of 30, 60 and 90 kg P_2O_5 as fertilizer. Data revealed that 79%, 88% and 81% of the trials showed positive yield responses to applications of 30, 60 and 90 kg P_2O_5 /ha, respectively. However, in comparison, only 67%, 61% and 25% of these showed economic benefit for the same doses, respectively. Based on this data, additions of 90 kg P_2O_5 /ha for maize production would be unprofitable. Therefore, the economic optimum for P fertilization appears to range between 30 and 60 kg P_2O_5 /ha as TSP. This range may be taken as a preliminary indicator to design further experiments with a more adaptive and local nature, and constitutes an important outcome of the regional trials.

In general, the response to S was small across the region. In 1990, application of 20 kg S/ha (as calcium sulfate) in the absence of P, produced a mean yield response of 0.33 ± 0.46 ton/ha. However, in the presence of P (60 kg P_2O_5 /ha as TSP), the effect was only 0.12 ± 0.34 ton/ha, suggesting a possible interaction between P and S. The nature of the possible interaction between P and S is discussed by the papers of Gordón et al. (p.105) and Name et al. (p.121). An economic evaluation of S application as calcium sulfate in one location (Cuyuta, Guatemala) in a long-term experiment (6 cycles) is presented in the paper by Sain and Valladares (p.95). This paper also illustrates important methodological issues for economic evaluation of trials with residual effects.

Research on Conservation Tillage

Research on conservation tillage is closely related to research on legume interseeding and P and S fertilization. Hence over 60% of the trials conducted by the Regional Program were planted under zero-tillage. The main objective of this project is to validate conservation tillage with residue management as a viable alternative for producing maize in sloping soils across Central America and the Caribbean. Other objectives include the identification of possible agronomic and/or socioeconomic limitations for the adoption of this technology by farmers in specific regions.

Results obtained so far suggest that a minimum level of residue as mulch is required for conservation tillage to be effective in erosion control and soil maintenance. Agricultural systems that emphasize intercropping/relay/rotation of several high biomass producing crops (e.g. maize-sorghum) present suitable characteristics for successful implementation of this technology. Preliminary results from experiments, implemented during 1990 and 1991 in El Salvador and aimed at evaluating different levels of residue, suggest that a minimum of 10 ton/ha of residue is appropriate to cover the entire soil surface and provide visible evidence of erosion control. However, these experiments are still in progress.

Socioeconomic studies by the regional program have focused on understanding the adoption process of conservation tillage practices by farmers in the area of Metalío-Guaymango (El Salvador), where over 3 thousand hectares of a maize-sorghum system have been planted under zero-tillage for the last 10-15 years. The study revealed that the adoption process of this technology was complex, where institutional factors, land-ownership, technology transfer, and local socioeconomic conditions played their role. Curiously, in this area, the generation and validation of technology within the classical scheme of on-farm research did not play its ascribed role, as the transference of conservation tillage technology occurred without previous specific on-farm experimentation and validation within the area. The institutional aspects of adoption of conservation tillage in this area are described in the paper by Calderón et al. (p.73).

Methodological Studies

Experimental Precision

One of the most interesting methodological aspects derived from regional trial data has been to examine current levels of experimental precision for maize experimentation across the region. Estimated mean value of experimental error for 55 trials conducted in 1989, involving different technological components (on-farm trials, experiment station trials, P and S fertilization trials, legume intercropping trials, and hybrid evaluation trials), and across multiple environments, was $0.40 \pm 0.22 \text{ ton}^2/\text{ha}^2$. This value of experimental error implies a standard error of difference (S_d) of around 500 kg/ha for a typical trial with 3 replicates per treatment. The magnitude of S_d imposes severe limitations to declare statistically significant differences between treatments using the current methodology of field experimentation (minimum grain yield differences between treatment means necessary to declare 5% significance usually lie between 1.0-1.5 ton/ha), and has implications for the selection of experimental factors and experimental design (see the paper by Barreto and Raun, Regional trials 1989). Unifying criteria for integrated statistical and economic analysis of research results is one of the most important methodological objectives of the current phase.

Harvested plot size for the regional legume interseeding trials was increased by 100% in 1990 compared to 1989 (from 10 to 20 m²). Although these data require more analysis, experimental precision seems to have increased with the expansion in plot size. The average error mean square for 13 trials in 1990 was $0.27 \pm 0.21 \text{ ton}^2/\text{ha}^2$ compared to $0.37 \pm 0.23 \text{ ton}^2/\text{ha}^2$ for 11 trials in 1989. Although the improvement in precision is small (approximately a reduction of 78 kg/ha in S_d), it serves to illustrate the feasibility of modifying current field plot technique to increase experimental precision. Based on these results, the minimum harvested plot size for maize trials should be no less than 20 m² to get reasonable levels of precision in field experiments.

Yield Components of Maize

Another important methodological aspect has been to try to understand the biological basis of the observed yield variability across the regional trials. Using data from 34 regional trials, the paper by Bolaños and Barreto (p.9) presents an analysis of the maize yield components followed by a discussion of some of the factors limiting maize yields throughout Central America. Despite a relatively uniform and high level of technology across all regional trials, a wide range in yield potential (1.0 to 7.0 ton/ha) was observed. Such variability could not be directly explained by any environmental or soil parameter (rainfall, slope, soil chemical analysis) measured at each site, rather, it appeared strongly dependent on variation of yield components, namely, plants (pl/ha) or ears per hectare (ears/ha) and mean ear weight. Total biomass production per plant (biom/pl) or hectare (biom/ha) were also strongly related to yield. In general,

environments with low mean yields were those with low number of ears/ha, low mean ear weight and low biomass. Correspondingly, environments with high yield level were those with a large number of ears/ha, large mean ear weight, and large biomass. If experimental plots managed by researchers had such high level of variability, the situation must be worse in farmers fields. This study suggests that a useful strategy for diagnosing more effectively the limitations to yield is to routinely determine the yield components, and relate them to cultural practices, environmental variables including soil parameters. Nevertheless, these results should be interpreted with caution as yield components are not entirely independent from each other. Rather they are all derived from a few selected quantities (e.g. pl/ha, mz/ha, and grain and stover yield in ton/ha) which are not themselves independent from each other (e.g. without plants there are no ears, without ears there is no grain yield). This might account for the high degree of linear correlation observed for several of the relationships among yield components.

Analysis Across Multiple Locations

Analysis across several locations must consider both the consistency of the treatment main effects, as well as the nature of the treatment x location interaction. Although the regional trials have provided useful data for evaluating the consistency of treatment main effects across multiple environments, the observed variability in yield is very large. To deal with that, in most of the papers, treatment effects are evaluated using an analysis of the yield differential between paired preplanned treatment comparisons (e.g., 30 vs 0 P, maize vs maize+legume), instead of the traditional presentation of the absolute yields of different treatments. These yield differences are then related to the mean yield of the site or to environmental or soil parameters. This methodology has been very useful in evaluating results across multiple environments. The structure of the regional trial database is an accurate reflection of the progress achieved in data analysis by the regional program.

Annual Workplan and Orientation for 1991

The 1991 Annual Workplan for the Maize Regional Program identifies 24 specific activities related to the Agronomy-Economics research described above. The successful completion of these activities will ensure meeting the objectives set forth in the Planning Meeting in March of 1990 in El Salvador. In 1991, the regional trials have been reoriented to include several experimental treatments more specific to the areas where the trials are conducted, without sacrificing the regional context. This includes socioeconomic characterization and possible adoption/insertion of the best treatments into the maize farming systems. Given the uncertainty of the future, it is important to utilize the information generated by the Central American Regional Maize Program to fuel more local, specific adaptive research in each of the countries.

