Sustainable Production Systems

Economic and Sustainability Evaluation of New Technologies in Sorghum and Millet Production in INTSORMIL-Priority Countries

Project PRF-205

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Summary

The focus of this past year's research has been on the diffusion of new technologies. Information was a critical variable for successful introduction of the new sorghum cultivar and inorganic fertilizer in Tigray, Ethiopia and also for inorganic fertilizers in Niger. From this and other research, we are convinced that the main determinant of technology introduction is for farmers to see it in the field in conditions similar to their own. Governments can accelerate the diffusion by creating an environment in which it is more profitable to use the technology and by improving the functioning of input markets.

There were highly significant complementary effects from the combination of manure and inorganic fertilizer. This is further evidence that these two inputs are complements rather than substitutes.

There was a preference for using the *Striga*-resistant cultivars on the lighter soils, thereby taking advantage of their earliness. Conversely, the inorganic fertilizer was concentrated on the vertisols. In the last two years, various water-retention techniques have been introduced on a large scale in this region of Tigray to reduce the runoff on the crusting soils.

A continuing problem in Niger is the governmental emphasis on maintaining a low price of millet for the benefit of urban consumers. This reduced profitability decreases the incentives to intensify production. Nevertheless, an increasing diffusion of various types of fertilization was being undertaken even in this low rainfall, high-risk agriculture. This indicates again the importance of the demonstration and information variables discussed above.

In Mali, modeling for the agricultural sector compared alternative research-developmental strategies. Investments in sorghum for the semiarid zone gave higher returns to society than either sorghum for the higher-rainfall zone or maize for the same zone. This resulted from the larger yield gap (difference between experiment-station and average-farmer yields) and the larger number of sorghum producers in the dryland zone. Investment in dryland agriculture can not only reduce poverty but also is a high-return activity.

Objectives, Production, and Utilization Constraints

The general objectives of this research are:

- Estimate the potential effects of new technologies
- Identify constraints to their introduction
- Recommend complementary policies to accelerate the introduction process.

In this period there were three primary areas of research: (1) a diffusion study in Tigray to estimate the effects of the adoption of *Striga*-resistant sorghums and associated technologies), (2) an analysis of the introduction of inorganic fertilizer into a semiarid region of Niger in which there have been long-term inorganic fertilizer experiments, and (3) a comparison of the returns to the society of three alternative research-development strategies in southern Mali involving sorghum and maize.

Research Approach and Project Output

Striga-Resistant Sorghums and Associated Technologies in Tigray, Ethiopia

In last year's annual report, we described the results of a survey of 90 farmers of new technology introduction into the dryland regions in the far north of Ethiopia. After seeing the *Striga*-resistant cultivars in regional trials, farmers had pushed the government to release them as new cultivars. Three new *Striga*-resistant cultivars were released in 1999 and 2000. The diffusion is still in the early stages, but we were interested in the factors associated with the initial rapid diffusion and in the complementarity of the various new technologies.

In the statistical analysis, we analyzed the diffusion process for both the adoption of the *Striga*-resistant cultivars and of inorganic fertilizer (Tables 1 and 2). For both technologies, the most important factors were farmers' information and knowledge about technology performance, profitability, and liquidity. For the *Striga*-resistant cultivar, there were several ways of measuring farm-level information; two of them were highly significant. Participation in the local administration of farmers' groups (EXEC) helped inform and give farmers access to the new cultivars. The cultivars were still very new in the community. Forty-nine percent of the non-adopting farmers had not even heard about them. A variable for farmers' perceptions of the new technologies with respect to their technical characteristics (TECHPRCP) was also highly significant.

A variable for the farmers' perception of the riskiness of agriculture (RISKPRCP) with respect to rainfall was also highly significant. Besides *Striga* resistance, the new sorghum cultivars are earlier than traditional cultivars. Hence, they have a higher probability for drought escape. This was undoubtedly one of the factors farmers appreciated in the first year of trials, 1998, when there was a drought. The downside of earliness is that there is less potential to respond to inputs because the plant is in the field less time.

There was a significantly higher diffusion of the new cultivars on the lighter soils. On these soils the water-availability problem generally results from the rapid percolation of water through the soil beyond the reach of the plant.[1] The significance of this variable (SOIL) and of the variable indicating greater perception of rainfall risk indicated an appreciation of the drought-escape potential of the new cultivar.

Also interesting were the variables that were not significant. We expected a positive interaction between the new cultivars with both the water-retention technologies (WRT) and inorganic fertilizers (FERT), but there were no significant effects. Water-retention technologies were being pervasively introduced (see the annual report of last year); the earliness of the new cultivars resulted in less potential for a fertilizer response. Nor did the number of livestock units

[1] On the heavier vertisols, also frequently found in the region, the problem of water availability is usually associated with runoff though water logging can also be a problem especially on vertisols.

Table 1. Determinants of the diffusion of the *Striga*-Resistant sorghum cultivars in Tigray, Ethiopia (Tobit).

Variable	Normalized coefficient	T-ratio
EXEC	0.91937	2.6176**
FRMSZ	0.11155	1.3786
TLU	-0.37326E-01	-0.88678
FERT	0.80013	1.1223
WRT	0.30112	0.61822
SOIL	0.80792	2.1597**
TECHPRCP	3.9719	5.7727***
RISKPRCP	0.25748	2.0379**
Log-likelihood function	-15.309278	
Log-likelihood ratio	3.697	

Mean square error = 0.19853257E-01
Mean error = 0.26605625E-02
Squared correlation between observed and expected values = 0.41176
*** significant at 1%
** significant at 5%

Source: Wubeneh, Nega. 2002. "Farm Level Adoption of Resistant Sorghum Varieties and Inorganic Fertilizers in the Tahtay Adiabo Woreda of Tigray Region, Ethiopia,"unpublished Master's thesis. West Lafayette, IN: Purdue University, Dept. of Agricultural Economics.

Variable definitions:
EXEC - binary variable: 1 if the farmer is an official of the local administration; 0 otherwise.
FRMSZ - farm size measured in hectares.
TLU - tropical livestock unit.
FERT - quantity of fertilizer used on sorghum measured in kg ha^{-1}.
WRT - water-retention techniques measured as a binary variable:1 if the farmer is using water-retention techniques and 0 otherwise.
SOIL - soil type measured as a binary variable: 1 if the soil texture is light and medium (Luvisols, Leptisols, and Cambisols); 0 if heavy texture (Vertisols).
TECHPRCP - Index measuring the farmer's perception of the characteristics of the new cultivars.
RISKPRCP - Farmer's perception of rainfall risk measured by the farmer's subjective estimates of the probability of poor years.

Table 2. Determinants of the diffusion of inorganic fertilizer in Tigray, Ethiopia (Tobit model).

Variable	Normalized coefficient	T-ratio
FMLYG13	0.20265	2.0068**
FRMSZ	-0.22693	-2.9477***
EXTEN	0.83570E-01	2.5707**
WRT	0.13945	0.4224
MANURE	0.25902E-01	2.5206**
SOIL	-0.52770	-2.0011**
RISKPRCP	-0.63765E-01	-0.6372
Log-likelihood function	-2.0941595	
Log-likelihood ratio	0.535484	

Mean square error =0.77807751E-02
Mean error = -0.41727183E-02
Squared correlation between observed and expected values = 0.24336
** significant at 1%
** significant at 5%
* significant at 10%

Source: Wubeneh, Nega. 2002. "Farm Level Adoption of Resistant Sorghum Varieties and Inorganic Fertilizers in the Tahtay Adiabo Woreda of Tigray Region, Ethiopia," unpublished Master's thesis. West Lafayette, IN: PurdueUniversity, Dept. of Agricultural Economics.

Variable definitions:
FMLYG13 - number of adults aged 13 years and older in the household.
FRMSZ - farm size measured in hectares.
EXTEN - number of times the farmer has been visited by Extension agents during the season.
WRT - water-retention techniques measured as a binary variable: 1 if the farmer is using water-retention techniques and 0 otherwise.
MANURE - quantity of manure used in quintals.
SOIL - soil type measured as a binary variable: 1 if the soil texture is light and medium (Luvisols, Leptisols, and Cambisols); 0 if heavy texture (Vertisols).
RISKPRCP - Farmer's perception of rainfall risk measured by his subjective estimates of the probability of poor rainfall years.

have a significant effect as expected. The farm-size variable was almost significant.

Shifting to the diffusion of inorganic fertilizer, information was again highly significant. In this case it came from extension visits (EXTEN). Being in the leadership of the farmers' groups[2] did not matter here since this technology has been out a sufficiently long time for the extension service to be knowledgeable and promoting it. Nor was the risk perception variable significant. Both diffusion equations indicate the importance of information for accelerating the introduction of the two new technologies, though in the two cases information came from different sources.

Family size was positively significant, indicating the importance of family labor in the adoption of inorganic fertilizer. This technology increases the demand for labor. Farm size had a significant negative sign. Smaller farms produce more intensively and use more inputs. Manure use was highly complementary to inorganic fertilizer, as expected. The soil variable had the opposite sign from the case of the new cultivars. Farmers preferred to fertilize on the heavier vertisols as these soils have higher initial soil fertility and water-holding capacity than the sandy soils. The further addition of more nutrients has a higher chance to be successful in increasing yields. Again, the water-retention variable had no effect; that was a surprise, but the dummy variable for soils was picking up the soils with higher water holding capacity.

Fertilization of Millet in Niger. In the Sahel there is much debate on the profitability and riskiness of fertilizers. One hypothesis to explain the observed lag in diffusion of fertilization is that farmers need to see concrete results from fertilization before they will adopt. In the farm-level observations in the semiarid zone of Niger, 100 millet producers were interviewed in five villages. In two of these villages there had been long-term soil-fertility experiments so farmers there were knowledgeable about the potential responses and variability of response to inorganic fertilizers.

With liberalization (removal of state intervention and elimination of fertilizer subsidies) and the continuing efforts of government to prevent the millet price from increasing when there are disruptions to supply, the real price of millet (relative to the price of inorganic fertilizer) declined substantially in the '90s (Abdoulaye, 2002). Nevertheless, in certain regions of semiarid Niger, farmers continue to utilize small quantities of inorganic fertilizer on millet. What are the factors associated with this diffusion of fertilizer?

Exposure to the on-farm trials has a highly significant effect on the adoption of fertilization (Table 3). The price of fertilizer relative to the price of millet also had a significant positive effect. Families with migrating family members

Table 3. Determinants of the diffusion of inorganic fertilizer in Niger (Tobit model).

Independent variables	
Relative price of fertilizer Migration	-21.64(-2.02)**
Wealth	12.64(1.91)*
On-farm trials	2.56 (2.27)**
Manure use	37.75(2.26)**
Other activities	19.35 (0.81)
Area	25.44(1.51)
Constant	-4.67(-0.77)
	2.44 (0.47)
Number of observations	99
Overall significance level	0.28

Log-likelihood function = -363.74. Likelihood ratio test: ^{2} = 27.22* with 7 degrees of freedom. The numbers in parentheses are values of T-statistic for each coefficient. (*) indicates significance at 10% level and (**) indicates significance level of 5%. Overall significance level is the the squared correlation between observed and expected values.

Source: Abdoulaye, Tahirou, and John H. Sanders. 2002. "Economics of Fertilizer Use in Semiarid African Agriculture: Niger Experience." Mimeo. West Lafayette, IN: Purdue University, Dept. of Agricultural Economics.

have the cash that they bring back as a source of liquidity for buying fertilizer. Higher wealth means not only more liquidity but also the increased ability to take risks. Manure use had the expected sign, indicating complementarity with inorganic fertilizer but it was not significant. Nor were the Other Activities (another liquidity variable) or Area variables.

Introducing New Sorghum Technologies in Mali. During the last two decades of support to agricultural development in developing countries, there has been a concentration on irrigated and higher-rainfall regions. As malnutrition and poverty have been returning to the development agenda there is a focus shift to the drylands primarily for income distribution reasons as these are the regions where there is a concentration of the rural poor.

However, there are also efficiency reasons for shifting attention to the drylands. Where water availability and soil fertility can be improved, the drylands have a comparative advantage over the higher-rainfall regions due to the combination of more hours of sunlight and less disease pressure. The highest crop yields in the world are obtained in the former drylands, such as in Israel, Australia, and California. Often the new system includes irrigation, but there are a series of technologies to better use the available water as alternatives where irrigation is not technically or economically feasible. On the heavier soils where crusting is the major problem, these are water-retention technologies. On the sandier soil, it is often critical to slow infiltration so that it is accessible to the plant.

With the previous concentration on crops in the higher rainfall or irrigated regions, much of the yield gap between farmer and experiment stations often has been closed. Hence, there are cases as in Mali where there is a larger yield gap presently in the dryland regions. In Figure 1, note the yield-gap comparison between sorghum and maize.

Using a sector model, Vitale (2002) investigated the hypothesis of higher social returns from concentrating on the dryland crop. Vitale evaluated the returns to society from

[2] For the new cultivar, extension visits were not a significant variable either with or without the variable for membership in the leadership of the farmers' organization.

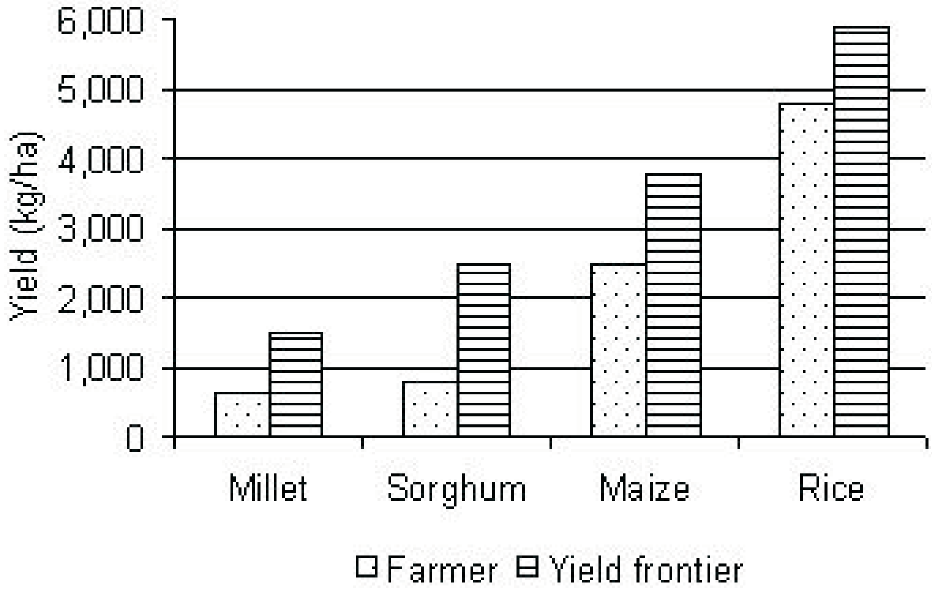

Figure 1. Experiment station and farmer yields for the cereals in Mali
Source: Vitale and Sanders, 2002, p. 24.

programs to introduce three new technologies – new technology in sorghum first for the higher-rainfall region and then the lower one, and new technology in maize for the higher-rainfall zone. For the semiarid zone, ridging for water retention has already been extensively introduced into southern Mali. It was only necessary then to introduce moderate inorganic fertilizer levels and the new sorghum cultivar.[3] For the higher-rainfall regions, the new technology also involved more fertilizer (as farmers were already using moderate fertilizer levels) and new cultivars. The new technology for sorghum in the dryland areas gave a smaller yield increase than either technology for the higher-rainfall zone. However, there were substantially more farmers in the dryland region producing sorghum. Even with conservative assumptions about the percentage of farmers adopting the new technology, the returns to society were considerably higher with a concentration on the sorghum technology for the semiarid zone than on either technology for the higher-rainfall zone (Vitale and Sanders, 2002). So for both efficiency and equity (income distribution) reasons, there are now good reasons for national agricultural research organizations and donors to put more attention on the lower rainfall regions.

Networking Activities

Workshops

After submitting a two-volume report on the contract for IFAD to identify new technologies for the drylands of the Horn, a workshop was held by IFAD with financial support from USAID/REDSO and technical coordination of INTSORMIL. The workshop took place in Nairobi in November 2001. The contributors to the fieldwork gave reports on their particular contributions. Sanders gave an overall summary of the report with an emphasis on future projects; all the team members responded to questions from the agricultural professionals representing the six countries involved. Then discussion sections were held and reports made back to the plenary group for recommendations on project proposals to respond to the constraints identified for introducing new technologies for the drylands of the Horn at a more rapid rate. After this workshop, Sanders and the other team participants, including Kidane Georgis from EARO and Peter Esele from NARO,[4] wrote five research proposals for IGAD on various aspects covered in their two-volume diagnostic of the drylands in the Horn.

Sanders attended an Experts Consultation on Agricultural Development in the Sahel in Bamako, Mali from April 23-26. This meeting was called by ICRISAT at the request of the Common Fund for Commodities, to which ICRISAT had submitted a research proposal. Sanders made two presentations, one on the analysis of factors determining the productivity of millet and sorghum in West and Central Africa and the other on the INTSORMIL collaborative program in the region. Then Sanders spent a week working with Barry Shapiro on a joint project between ICRISAT and INTSORMIL on marketing new millet cultivars in four Sahelian countries. This project evolves out of the millet re-

[3]Some demand expansion and increase in liquidity available were also required but the former is already being observed and the latter will naturally occur as the technology process enables higher incomes and these higher incomes allow increased liquidity for input purchase the next season.

[4]EARO and NARO are the national agricultural research agencies in Ethiopia and Uganda, respectively.

gional network led by Ouendeba Botorou . Presently, a new class of entrepreneurs is developing in several Sahelian countries that make processed products, such as couscous of millet, from the higher-quality white sorghums. Demand is rapidly increasing in urban areas of the Sahel and there have been exports to Europe targeting the migrant community. Several of the women entrepreneurs complained that they have not been able to buy sorghum at a sufficiently rapid rate to respond to the rapidly increasing demand. So the project is seeking to improve the ties between entrepreneurs and farmer cooperatives. The farmers will produce the higher-quality white sorghums; there are advance contracts. Because of little or no experience with advance contracts, there is a high probability of contract default by one side or the other. Various NGOs are involved in the four countries and are trying to reduce this risk to the gradual evolution of better-functioning markets. Our economics program considers this both as a developmental activity and a research project to estimate the income gains from various types of marketing innovation and the impact of these marketing improvements upon the diffusion of new sorghum technologies.

In May, Gebisa Ejeta asked Sanders to participate in a training workshop for Ethiopian extension agents involved in a project to disseminate new sorghum cultivars in Ethiopia with resistance to *Striga* and associated technologies (inorganic fertilizer and water-retention techniques). This project was funded by the USAID Disaster Relief Office since it was a response to the regionalized famine problems in the drylands of Ethiopia in 2000. Sanders made a presentation on the economics of sorghum technology introduction and interacted with the workshop participants during the four-day seminar. He also consulted with various EARO economists during this stay in Ethiopia.

Research Investigator Exchanges

In the workshop in Mali of May 2002, we began working with Ouendeba Botorou , director of the millet network for West and Central Africa, on a marketing project to facilitate the new millet-processing entrepreneurs in obtaining a regular supply of high-quality white sorghums from a number of cooperatives in four Sahelian countries. We plan to provide field support for estimating farmer incomes and the contributions from various marketing innovations to the incomes of these farmers. This will lead to an ICRISAT project proposal by the end of 2002 for an expanded marketing research project to encourage and facilitate the production and marketing of the higher food quality millets.

Publications and Presentations

Book Chapters, Book Reviews, and Proceedings

Shapiro, Barry I., and John H. Sanders. 2002. "Natural Resource Technologies for Semiarid Regions of Sub-Saharan Africa," Ch. 20 in C.B. Barrett, F. Place, and A.A. Aboud (eds.), Natural Resource Management in African Agriculture: Understanding and Improving Current Practices, pp.261-264. New York, NY: CABI Publishing

Sanders, John H., and Mohamed Ahmed. 2001. "Developing a Fertilizer Strategy for Sub-Saharan Africa" Ch. 16 in Sustainability of Agricultural Systems in Transition, ASA Special Publication No. 64, pp. 173-184. Madison, WI: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Sanders, John H., 2001. "Another World Food Scare?" Review of John Manning, Food's Frontier: The Next Green Revolution. North Point, NY: Farrar, Straus and Giroux. *Science* 291:1707-1708.

Dissertations and Theses

Abdoulaye, Tahirou A., "Farm Level Analysis of Agricultural Technology Change: Inorganic Fertilizer Use on Dryland in Western Nigeria," Ph.D., 2002.

Presentations

John H. Sanders, "Principal Results of the IGAD Study of New Technology Introduction into the Drylands of the Horn Countries and Implications for Future Projects," presented to the IGAD/REDSO/INTSORMIL six-country workshop to review the two-volume report of the team of consultants, Nairobi, Kenya, November 2001.

John H. Sanders, "Constraints and New Technology Development in the Sahel," presented to the Experts Committee meeting organized by ICRISAT and CFC, Bamako, Mali, April 2002.

John H. Sanders, "The Role of INTSORMIL in Agricultural Development in West and Central Africa," presented to the Experts Committee meeting organized by ICRISAT and CFC, Bamako, Mali, April 2002.

John H. Sanders, "The Economics of New Sorghum Technology Introduction," presented to the Workshop on the Diffusion of New Sorghum Cultivars with *Striga* Resistance, Nazareth, Ethiopia, May 2002.

Cropping Systems to Optimize Yield, Water and Nutrient Use Efficiency of Pearl Millet and Grain Sorghum

Project UNL-213
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Summary

Principal investigators in INTSORMIL Project UNL-213 continue with international research efforts related to nutrient management and use efficiency in West Africa and Central America. Preliminary pearl millet grain yield responses to microdose fertilizer application have been mixed, while larger basal fertilizer applications increased grain and stover yield of both population hybrids and local varieties. Research showed that an animal traction zaï system produced similar yield to the traditional zai system, but required 22 man-hours less labor per hectare. In Central America, nitrogen application increased sorghum grain yields quadratically for both photoperiod sensitive and insensitive varieties. Little difference in nitrogen use efficiency was found among the photoperiod insensitive varieties tested, indicating that broader screening of germplasm in Central America sorghum breeding programs will be needed to identify and develop high nitrogen use efficient sorghum varieties.

Research in the United States indicates that pearl millet has low yield potential in the Great Plains and is not a viable alternate crop except in late planting situations, such as double cropping and as an emergency replant crop. Study of "old" and "new" maize and sorghum hybrids indicate that maize had higher yield potential than sorghum in 1960, and that maize grain yield has increased more rapidly than grain sorghum for both dryland and irrigated situations. Plant breeding programs must increase sorghum grain yield potential to maintain or increase sorghum's role in Great Plains agriculture.

INTSORMIL Project UNL-213 emphasizes capacity development through graduate education, short-term training,

and coordination of the Central America Regional Program. Graduate students from Burkina Faso, Niger and the U.S. are completing degrees, and the lead Principal Investigator organized the Central America Sorghum Research and Planning Conference held in February 2002.

Objectives, Production and Utilization Constraints

Objectives

- Implement multi-year research on microdose, N and P fertilizer application on pearl millet grain yield, nutrient removal, and changes in soil nutrient levels in Burkina Faso, Mali and Niger.
- Implement research on mechanized zaï production system for pearl millet in Burkina Faso, weed control interactions with fertilizer rates in Mali, and fertilizer rate by plant population for hybrid grain sorghum seed production.
- Conduct research on adaptation, production practices, and grain quality for population hybrids in West Africa.
- Actively participate in the West and Central Africa Pearl Millet Research Network (ROCAFREMI) agronomic research and annual meetings in West Africa.
- Determine the planting date and row spacing recommendation for dwarf pearl millet hybrid production in eastern and western Nebraska.
- Evaluate grain sorghum and maize hybrid from the 1950s, 1970s and 1990s under low and high water holding capacity soils, wide and narrow rows, and dryland and irrigated environments.
- Conduct N rate and N use efficiency studies for grain sorghum production in El Salvador and Nicaragua.
- Increase research human capital in West African countries where pearl millet is an important crop through graduate education, short-term training, mentoring former students upon return to their home country, and active participation in the West and Central Africa Pearl Millet Network.
- Collaborate with national extension services and NGO/PVOs in transferring improved pearl millet agronomy practices.

Constraints

This project has focused primarily on crop production systems which increase the probability of obtaining higher pearl millet and sorghum grain and stover yields. This involves systems which increase nutrient and water availability to growing crops, and produces desired uniform stands. Present efforts emphasize crop rotation, intercropping, inorganic and organic fertilizer management, and residue management interactions with traditional and improved cultivars. These cropping systems research efforts require long-term investments of well-trained, interested scientists and stable funding. Education of additional scientists in crop production and continued support of their work after return to their home countries is needed to improve productivity of cropping systems and to maintain the soil/land resource.

Research Approach and Project Output

Pearl millet and grain sorghum are usually grown in stressful environments with high temperatures, lack of predictable water supply, fragile soils with low nutrient status, and limited growing season length. Lack of water is usually considered to be the most critical environmental factor controlling growth and limiting yield in Africa, but a source of nitrogen and/or phosphorus often is more critical. This is especially true for intensive cropping systems using improved cultivars on degraded land. Nutrient use and water use efficiencies are closely interwoven with higher yields possible with improved cropping systems utilizing improved cultivars. Since human capital for research and extension activities are very limited for pearl millet producing areas in West Africa, project activities are generally conducted as either graduate education programs for scientists from this region, mentoring collaborative activities upon return of former graduate students, or collaborating with pearl millet research network (ROCAFREMI). Studies have been initiated with new collaborators in Central America on nitrogen fertilizer management and identification of nitrogen efficient genotypes for grain sorghum production which is also a critical issue in the region. In the U.S. Great Plains, production practice recommendations for planting date, nitrogen rate and water supply for high yielding, dwarf hybrids are being determined to help adoption as an alternate grain crop. This complex interaction of water, nitrogen, phosphorus, cultivars and yield enhancing production practices is the focus of Project UNL-213s research efforts.

Domestic (Nebraska)

Water Supply Effect on Pearl Millet Grain and Stover Yield (Nouri Maman, Ph.D. Thesis)

Research Methods

The experiment is being conducted on a Keith silt loam under a linear move irrigation system with drop nozzles at the High Plains Agricultural Laboratory located at Sidney, NE (west) in 2000 and 2001. The experiment was conducted using a randomized complete block design with a factorial (2 x 4) treatment arrangement and three replications. Factor 1 was the pearl millet hybrid (68A × 086R) and one grain sorghum hybrid (DK 28E). Factor 2 was composed of 4 different water regimes. The water regimes consisted of; (i) Control, rainfed; (ii) Full water supply at all growth stages (apply water to bring soil moisture level to 80% field capacity any time it falls to 70% field capacity); (iii) Water supply at boot stage, and (iv) water supply at grain fill stage. Soil water was measured using neutron probes. Grain and stover yields were collected at harvest, and seasonal grain and biomass water use efficiencies (WUE) were calculated. A similar study was conducted at Mead, NE (east) using a furrow irrigation system. Data were analyzed using analysis of variance procedures.

Research Results

At Sidney no rainfall occurred during the 2001 growing season, thus extremely low grain and stover yields of both pearl millet and grain sorghum were produced (Table 1). In 2002, Sidney produced higher yields with good rainfall, and in Mead in both years the grain yields were greater than at Sidney as the result of higher water holding capacity and a less stressful environment. No crop by water regime interaction occurred, thus the response of both crops to water regime were similar. Grain sorghum produced higher yield than pearl millet in all production environments, indicating limited potential for pearl millet as a new alternate grain crop. Full irrigation increased the average grain yield of the crops by 1.0 to 3.5 mg ha^{-1}. Partial irrigation increased yield, but to a lesser degree than full irrigation. Partial irrigation at the grain-fill stage increased grain yield more than irrigation at the boot stage. Yield component analysis indicated that water regime only had an influence on panicles/m^2 and kernels/panicle in the most stressful production environment of Sidney in 2000. Kernel weights were increased with single irrigation at mid-grain fill and with full irrigation. No one yield component stood out as being more important in yield determination than the others. At Sidney, the crops used similar amounts of water in both years, but grain sorghum had a 3 to 7 kg grain/mm higher grain water use efficiency. The biomass water use efficiencies were similar for the two crops in 2001, while grain sorghum had a 5 kg dry matter/mm higher biomass water use efficiency in 2000. Grain sorghum produced a higher yield and had higher water use efficiencies than pearl millet in these diverse production environments, thus without a large boost in yield potential, pearl millet has little potential as a crop in Nebraska.

Nitrogen Response of Pearl Millet
(Nouri Maman, Ph.D. Thesis)

Research Methods

The pearl millet hybrids 68A×086R and 293×086R were planted in randomized complete block experiments with side-dress nitrogen fertilizer rates of 0, 45, 90 and 135 kg ha^{-1} and four replications in 2000 and 2001. The study was conducted in Sidney, NE (west) on a Keith silt loam soil with approximately 100 kg ha^{-1} residual nitrate-nitrogen and in Mead, NE on a Sharpsburg silty clay loam soil with approximately 25 kg ha^{-1} residual nitrate-nitrogen. Leaf nitrogen concentration, leaf chlorophyll concentration, grain and stover yield, and plant nitrogen uptake were collected. Data were analyzed using analysis of variance, and nitrogen response using single-degree orthogonal contrasts.

Research Results

Pearl millet grain yields were quite low at Sidney in 2000, intermediate at Sidney in 2001 and high at Mead in both years. The yield levels corresponded to the total season rainfall and distribution during the growing season. Nitrogen fertilizer application increased grain yield linearly at Sidney (from 1.17 to 1.54 mg ha^{-1} in 2001 and 2.8 to 4.0 mg ha^{-1} in 2002) and Mead (from 2.5 to 4.0 mg ha^{-1}) in both years, indicating that more than 120 kg ha^{-1} was required to maximize pearl millet grain yield in these environments. Although pearl millet is a N use efficient species, relatively high N rates are required to optimize grain yield production.

Planting Date and Row Spacing of Pearl Millet
(Siebou Pale, M.S. Thesis)

Research Methods

Studies were conducted between 1995 and 2001 to determine recommended planting date and row spacing for pearl millet hybrids was conducted on a silty clay loam and sandy soil site in Mead, NE (east), a loam soil in Sidney, NE (west), and a sandy soil site in Ogallala, NE (west-central). Sidney has low rainfall, short growing season. and efforts are being made to intensify wheat-fallow production systems by incorporating pearl millet as a summer annual crop in this region. The pearl millet hybrids 68A×086R responses to planting date, and narrow (38 to 50 cm) and wide (76 cm) row spacing were compared to the grain sorghum check DK28.

Research Results

Measuring air or soil heat units gave better recommendations than using day of year or soil temperature. Pearl millet planting time between 239 and 501 air or 236 and 529 soil heat units optimized yield in eastern Nebraska, while in

Table 1. Effect of water regime on pearl millet and sorghum grain yield and yield components at Sidney and Mead, NE in 2000 and 2001. Since no crop by water regime interaction occurred, data are averaged across crops.

Water regime	Grain yield			Panicles			Kernels/Panicle			Kernel weight		
	Sidney 2000	Sidney 2001	Mead	Sidney 2000	Sidney 2001	Mead	Sidney 2000	Sidney 2001	Mead	Sidney 2000	Sidney 2001	Mead
	- - - - - - - - - - Mg ha^{-1} - - - - - - - - - -			- - - - - - - - No./m^2 - - - - - - - -			- - - - - - - No./Panicle - - - - - - -			- - - - - - - mg/kernel - - - - - - -		
Rainfed	1.4	3.6	5.0	12.3	21.1	22.0	1226	1921	1859	9.8	15.1	16.8
Boot Irrigation	2.7	4.1	5.5	22.5	20.7	22.0	1275	2028	1826	10.4	15.5	17.6
Grain Fill Irrigation	3.0	4.6	5.8	17.5	19.6	22.0	1521	1933	1992	14.7	17.0	17.8
Full Irrigation	4.9	5.5	6.0	25.8	20.8	20.8	1902	2135	1972	13.0	17.0	18.2
	- F>P -											
Water Regime	<0.01	<0.01	<0.01	<0.01	NS	NS	<0.01	NS	0.04	<0.01	<0.01	<0.01
Contrasts												
Rainfed vs Irrigation	<0.01	<0.01	<0.01	<0.01	NS	NS	<0.01	0.04	NS	0.02	<0.01	<0.01
Full vs Partial Irrigation	<0.01	<0.01	0.01	0.07	NS	NS	0.03	NS	NS	<0.01	<0.01	NS
Boot vs Grain Fill	<0.01	<0.01	0.04	<0.01	NS	NS	NS	NS	0.02	NS	0.01	NS

western Nebraska, where elevation limits the growing season length, early planting at approximately 120 air or soil heat units was best. Pearl millet had a later planting time than sorghum even though pearl millet has a lower base temperature, and both crops had large planting time windows allowing flexibility in planting time without sacrificing yield. Pearl millet had 1.0 to 1.2 Mg ha^{-1} greater yield than grain sorghum when planted in late June or July, indicating that it has potential for replant or double crop situations. However, grain sorghum out-yielded pearl millet by 0.57 to 2.32 Mg ha^{-1} for normal planting dates in May and early June, thus grain sorghum is usually a more economical crop option than pearl millet.

Row spacing response was similar across locations, planting dates and the two crops. Narrowing rows from 76 to 38 cm increased the yield of both crops by 8 to 14% across the 15 year-location combinations in the study. Pearl millet and early-season sorghum producers should plant these crops in narrow rows to optimize grain yield production.

Grain Sorghum - Maize Hybrid Comparisons in Dryland and Irrigated Environments (Delon Kathol, M.S. Thesis)

Research Methods

A three-year study was initiated in 1999 to determine the importance and physiological basis for shift in dryland sorghum production to maize production in eastern Nebraska. Best hybrids were identified from the 1950s, 1970s and 1990s and produced in four environments each year. The environments are sandy loam and silty clay loam soil types, 76 and 38 cm row spacing, and irrigated and dryland water regimes. Grain yield and yield components, dry matter and leaf area, lodging and climatic data are being collected. Path correlation analysis will be used to identify relationships between grain yield and yield components, and stability analysis used to help identify crop/hybrid responses.

Research Results

Across years and production situations, altering row spacing had little effect on grain yield of both crops and crop-by-production condition interactions did not occur. In both years, hybrid within crop effects occurred ($P \leq 0.05$) and did not interact with the production situations used in the study. Averaged across five production situation-year combinations, sorghum yields increased from 6.8 for the 1950 hybrid to 7.05 mg ha^{-1} for the three 1970 hybrids to 7.5 mg ha^{-1} for the four 1990 hybrids, which suggests an increase in sorghum grain yield of 0.13 to 0.23 mg ha^{-1} /decade. Average maize hybrid grain yields increased from 8.55 mg ha^{-1} for the 1950 hybrid to 9.9 mg ha^{-1} for the three 1970 hybrids to 10.7 mg ha^{-1} for the four 1990s hybrids, which suggests an increase in maize yield of 0.68 to 0.4 mg ha^{-1} /decade. These data indicate that maize had higher grain yield potential than sorghum in the 1950s, and that maize grain yield has increased more rapidly than for grain sorghum.

International

Microdose Fertilizer Study (Burkina Faso, Mali and Niger)

Research Methods

Three-year central studies were initiated on-station in Burkina Faso (pearl millet), Mali (pearl millet on sandy and heavy soil, and grain sorghum on heavy soil) and Niger (pearl millet) in 2001. A randomized complete designed study was used with four replications. Treatments consisted of zero, microdose (cap full of complete fertilizer in the seed hill at planting), micodose + 20 kg ha^{-1} P, microdose + 40 kg ha^{-1} P, microdose + 30 kg ha^{-1} N, microdose + 60 kg ha^{-1}, microdose + 20 kg ha^{-1} P + 30 kg ha^{-1} N, and microdose + 40 . $^{-1}$ P + 60 kg ha^{-1} N. Each plot was sampled prior to initiating the experiment so that soil nutrient levels after three-years could be determined. Grain and stover yield, and N and P uptake in the grain and stover were collected. In addition, satellite studies were conducted on farms using zero, microdose and microdose + 20 kg ha^{-1} P + 40 kg ha^{-1} N treatments. One replication was planted per farm, and in the data analysis farms were considered to be replications.

Research Results

Preliminary results indicated that the yield increase due to microdose fertilizer application was not uniform across locations in the three countries, nor between station and on-farm sites. (Table 2). Microdose fertilizer application increased yield on-station in Niger and on a sandy soil in Mali, while no yield increase was in Burkina Faso nor on a heavy soil in Mali. The response on-farm was present in Burkina Faso, but not in Niger. Response to additional P and N application was also variable across countries, with Niger showing greater response to N, Burkina Faso to P, Mali sandy soil to combination of N and P, and no response to fertilizer on the Mali heavy soil. This study will be continued for two more years to document crop yield response and consequent changes in soil nutrient levels.

Population Hybrid by Production Environment Study (Cooperative with INTSORMIL Project ARS-213 - Burkina Faso, Mali, and Niger)

Research Methods

A randomized complete block designed study to evaluate a pearl millet population hybrid produced by INTSORMIL project ARS-213 with the best local variety under low and high yield environments was conducted in Cinzana (Mali), SARIA (Burkina Faso) and three locations in Niger in 2000 and 2001. The low yield environment consisted of no fertilizer with pearl millet planted in hills with 0.8m x 0.8m spacing. The high yield environment consisted of 23 kg ha^{-1} nitrogen, 20 kg ha^{-1} phosphorus and planting in hills with 0.8m x 0.4m spacing, except in Niger in 2000 where the hill

Table 2. Microdose, and N and P application influence on pearl millet grain yield in Burkina Faso, Mali and Niger in 2001.

	On-Station										On-Farm (7 to 10 Farms/Country)			
	Niger		Burkina Faso		Mali (Sandy)		Mali (Heavy)		Average		Niger		Burkina Faso	
Treatment	Grain	Biomass	Grain	Biomass	Grain	Biomass	Grain	Biomass	Grain	Biomass	Grain	Biomass	Grain	Biomass
	Mg /ha													
Zero	0.52	4.1	0.58	1.5	0.39	1.4	0.37	1.6	0.47	2.2	0.31	2.7	0.34	1.1
Microdose	0.64	6.3	0.53	2.2	0.61	3.0	0.27	1.3	0.51	3.2	0.33	3.4	0.56	2.3
Microdose + 20 kg/ha P	0.77	6.8	0.83	2.3	0.67	3.1	0.57	1.8	0.71	3.5				
Microdose + 40 kg/ha P	0.46	5.3	0.84	2.5	0.77	4.3	0.14	1.1	0.55	3.3				
Microdose + 30 kg/ha N	0.94	8.6	0.63	1.9	0.64	3.3	0.20	1.7	0.60	3.9				
Microdose + 60 kg/ha N	0.98	8.8	0.74	2.2	0.68	3.4	0.21	1.4	0.65	4.0				
Microdose + 20 kg/ha P + 30 kg/ha N	0.90	8.4	0.85	2.8	0.96	4.4	0.28	1.9	0.75	4.4	0.46	4.7	0.77	3.3
Microdose + 40 kg/ha P + 60 kg/ha N	0.98	8.4	1.08	2.7	0.89	5.3	0.36	2.0	0.83	4.6				
Probability	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.03	<0.01	<0.01
C.V. (%)	25	19	24	12	22	22	66	30			37	42		

Table 3. Grain and stover yield of the pearl millet population hybrid WA13 and a local variety in Burkima Faso, Mali and Niger in 2000 and 2001.

A. Grain yield		2000			2001				
Genotype	Production environment	Burkina Faso	Mali	Niger	Burkima Faso	Mali	Niger-Kalapati	Niger-N'Dounga	Mean
		Kg ha^{-1}							
WA13 (Population Hybrid)	Low	351	287	465	489	348	355	410	386
	High	617	517	577	834	338	650	469	572
Local	Low	497	767	872	597	723	82	156	528
	High	843	1112	673	1094	650	320	266	708

B. Stover yield		2001				
Genotype	Production environment	Burkina Faso	Mali	Niger - Kalapati	Niger - N'Dounga	Mean
		Kg ha^{-1}				
WA13 (Population Hybrid)	Low	832	1354	3184	3941	2328
	High	3358	1615	4020	5059	3513
Local	Low	1672	2383	1066	1309	1608

spacing remained constant. Data were analyzed using analysis of variance procedures.

Research Results

Grain yields were low in all cases, largely due to poorly distributed low seasonal rainfall in all locations in both years. The local pearl millet variety produced higher grain yield than WA13 in all three locations in 2000, and in Burkina Faso and Mali in 2001 (Table 3). The population hybrid produced higher grain and stover yields at the two locations in Niger in 2001, and appears to be better adapted to these production environments. The application of fertilizer and increasing plant population increased grain yield by 34 to 48%, and stover yield by 51 to 94% in these low-yield production situations.

Mali Weed Control Study

Research Methods

A randomized complete block designed experiment to evaluate the interactive effects of planting date, pearl millet genotype and hand weeding method on pearl millet grain and stover yield was initiated at Cinzana, Mali in 2000. Planting dates were early June and late June, varieties were India na 05 and Sanioba and six hand weed control methods (weed free, in-row weeding, between row weeding, in-row with soil ridging, in-row with mulching, and weedy check). Data were analyzed using analysis of variance procedures.

Research Results

Neither date of planting nor variety had a significant effect on pearl millet grain yield, although the later planting date tended to produce slightly more grain in 2000. Weeding method significantly affected both grain and stover yield with complete weeding or weeding in-row resulting in the greatest yield, between row and in-row with ridging or mulching resulting in intermediate yields, and the weedy check producing the lowest yield.

Mali Cover Crop Research (Minamba Bagayoko)

The species *Dolicos lablab*, *Fava larga*, *Canvalia ensiformis*, *Crotalaria juncea*, *Stizolobium deeringieanun*, *Crotalaria espectabilis*, *Stizolobium aterrimum*, *Cajanus* *cajan*, and *Crotalaria breviflora* were grown at the Cinzana Research Station to produce seed for future studies and provide initial evaluation as a dry season cover crop. Limited rainfall did not allow adequate production of seed, which is being repeated in 2002. Observations indicated that *Dolicos lablab* and *Canavalia ensiformis* grew well and protected the soil during most of the dry season.

Mechanized Zaï Research (Taonda Jean Baptiste)

Research Methods

The traditional zaï system composed of planting pearl millet seed in a small hole with a small amount of manure increases water infiltration on some soils and results in increased yield, but requires considerable land labor. Scientists at INERA have developed a mechanized zaï using animal traction. The objective of this study was to determine the effectiveness of the mechanized zaï to the traditional zaï and a flat-planted control across six different soil types in Burkina Faso. The study was conducted on 12 farms in three villages with each farm considered a replication. The soil types present on the farms was sandy, sandy loam, sandy clay, clay, gravelly clay and gravel.

Research Results

Pearl millet grain yields were over 1.0 mg ha^{-1} on the sandy and clay soil, approximately 0.7 mg ha^{-1} on the sandy clay, gravelly clay and gravelly soil, and 0.4 mg ha^{-1} on the sandy loam soil, but no interaction between soil type and planting method was found. The traditional and mechanical zaï produced similar grain and stover yields, which were more than 0.4 mg ha^{-1} more grain than the control and more than 1.4 mg ha^{-1} more stover. The mechanized zaï has potential to produce the yield advantage associated with the traditional zaï system through use of animal traction, but with greatly reduced labor and economic cost. The manual zaï system requires approximately 300-man hours of labor/ha while the mechanized zaï requires approximately 22 man hours/ha.

Production Practices for Hybrid Sorghum Seed Production (Seyni Sirifi)

Research Methods

A study was initiated in Lossa, Niger to determine recommended plant populations and nitrogen application rates for seed production of the sorghum hybrid NAD-1. The female inbred hybrid was planted at four plant populations and four nitrogen rates. Date of flowering, plant height and grain yield data was collected.

Research Results

Preliminary results indicate that hybrid seed production increased linearly with increasing nitrogen application, while plant population had little effect on the seed yield due to the female lines tillering ability. This research will be continued.

Central America Nitrogen Use Efficiency Studies (Wilfredo Castaneda, Leonardo Garcia and Orlando Tellez)

Research Methods

A two-year study was conducted at two locations in El Salvador and two locations in Nicaragua with the objective to determine if differences in nitrogen use efficiency between commonly used photoperiod sensitive and insensitive sorghum varieties and optimal nitrogen fertilizer rates for grain sorghum production, and to identify high nitrogen use efficient varieties. At each location a factorial combination of four (photoperiod insensitive) or six (photoperiod sensitive in El Salvador) grain sorghum varieties were grown with four nitrogen fertilizer rates in a randomized complete block design with four replications. Grain and stover yield, and N concentration of grain and stover at harvest were collected in 2001 to allow determination of nitrogen use efficiency. Data analysis was done using analysis of variance procedures, and orthogonal contrasts determined for nitrogen rate response.

Research Results

Among the photoperiod insensitive varieties only small differences in grain, biomass and fertilizer nitrogen use efficiency were found (Table 4), and it was concluded that screening of a broad base of germplasm used in breeding programs in El Salvador and Nicaragua would be needed to identify and develop varieties with high nitrogen use efficiencies. Nitrogen removal by sorghum plants was closely associated with whole plant yield (grain plus stover). Grain yield differences among sorghum varieties in El Salvador was only 0.6 (18% - 2000) or 0.7 mg ha^{-1} (20% - 2001). Similar differences among varieties were found in Nicaragua in 2001 (25%) but larger differences occurred in 2001 (41%). The variety INTA -2001 produced high grain and stover yields across years and locations in Nicaragua.

Among the photoperiod sensitive varieties, SCP-805 produce the highest grain yield and grain nitrogen use efficiency, while it produced less stover resulting in an intermediate biomass nitrogen use efficiency. The varieties Santa Cruz, Limay and Yalaguina produced high stover yields and low harvest indices. The variety ES-790 had a very high fertilizer nitrogen use efficiency, suggesting this variety is a good choice in low yield situations in which only small amounts of fertilizer are to be applied.

Grain sorghum yields usually responded to increasing nitrogen application rates in a quadratic manner, and seldom was yield maximized by the highest rate used. In El Salvador, 115 kg ha^{-1} nitrogen increased grain yield of photoperiod insensitive sorghum varieties from 2.5 to 4.5 mg ha^{-1} while 115 kg ha^{-1} nitrogen in Nicaragua increased yield from 2.5 to 3.9 mg ha^{-1} . Photoperiod sensitive sorghum relay intercropped with maize in El Salvador increased yield from 1.8 to 3.0 mg ha^{-1} with application of 95 kg ha^{-1} nitrogen. These impressive yield increases resulting

Table 4. Yield, N removal and N use efficiency for photoperiod sensitive and insensitive grain sorghum varieties in El Salvador and Nicaragua in 2000 and 2001. Data are averaged over four N application rates and two locations. Fertilizer N use efficiency for the lowest N rate of 47 kg ha^{-1}.

	2000	2001					
		Yield			N Use Efficiency		
	Grain	Grain	Stover	N Removal	Grain	Biomass	Fertilizer
	- - - - - - - - - - Mg ha^{-1} - - - - - - - - - -			Kg ha^{-1}	- -Kg DM/kg N - -		%
Photoperiod Insensitive							
El Salvador:							
Soberano	3.8	4.1	3.0	82	51	90	35
INTA-2000	3.4	4.0	3.8	86	46	90	44
CENTA RCV	3.5	3.7	3.0	72	52	94	56
INTA-2001	4.0	3.4	3.5	67	51	103	42
Nicaragua:							
CENTA RCV	3.2	3.1	7.9	93	34	118	
INTA-2000	4.5	3.5	6.0	85	41	111	
Pinolero 1	3.8	2.8	7.3	77	36	131	
Tortillero Precoz	3.5	2.8	4.4	69	41	104	
Photoperiod Sensitive							
El Salvador:							
86-EO-226	2.4	3.4	5.4	75	45	117	15
Santa Cruz	0.5	1.3	7.5	81	17	110	47
SCP-805	2.7	4.0	5.2	82	49	112	49
Limay	1.6	2.7	7.4	95	28	107	70
ES-790	2.5	3.6	6.0	89	41	109	129
Yalaguina	0.7	1.2	6.6	61	20	128	38

from nitrogen application are being tested on farmers fields in 2002.

Networking Activities

Workshops

INTSORMIL Central America Regional Program Research Results and Planning Workshop, Managua, Nicaragua, 27 - 28 February, 2002.

American Society of Agronomy Meetings, Charlotte, NC, 21-25 Oct., 2001.

Scientific Liaison Officer Workshop, USAID, Washington, D.C., 20-21 June, 2002.

Research Investigator Exchange

Pale Siebou (Burkina Faso) completed his M.S. degree (May 2002) and Nouri Maman (Niger) and Delon Kathol (U.S.A.) will complete degrees in the coming year.

Hosted visiting scientists Aildson Duarte, University of São Paulo, College of Agriculture (ESALQ) Piracicaba (SP), Brazil.

Research Information Exchange

Funds passed through to Burkina Faso, Mali and Niger to assist with collaborative research.

Visited INTSORMIL research efforts in El Salvador and Nicaragua in November, 2001.

Scientific Liaison Officer to the Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.

Publications and Presentations

Abstracts

Pale, S., S.C. Mason, T.D. Galusha, D.J. Lyon, R.N. Klein and R.K. Higgins. 2002. Planting time for pearl millet in Nebraska. Agron. Absts.

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Galusha, T.D., N. Maman, S.C. Mason and D.J. Lyon. 2002. Pearl millet and sorghum yield and water use efficiency in eastern Nebraska. Agron. Absts.

Maman, N., D.J. Lyon, S.C. Mason and R.K. Higgins. 2002. Timing of water application on pearl millet and sorghum yields in western Nebraska. Agron. Absts.

Kathol, D., S.C. Mason and T.D. Galusha. 2002. Yield components of new and old maize and sorghum hybrids. Agron. Absts.

Journal Articles

Samba Traoré, J. L. Lindquist, S. C. Mason, A. R. Martin, and D.A. Mortensen. 2002. Comparative ecophysiology of grain sorghum *(Sorghum bicolor) and Abutilon theophrasti* in monoculture and in mixture. Weed Res. 42: 65 - 75.

Masek, T.J., J.S. Schepers, S.C. Mason and D.D. Francis. 2001. Use of precision farming to improve application of feedlot waste to increase nutrient use efficiency and protect water quality. Commun. Soil Sci. Plant Anal. 32:1355-1369.

Soil and Water Management for Improving Sorghum Production in Eastern Africa

Project UNL-219
Charles Wortmann and Martha Mamo
University of Nebraska

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Summary

Activities to date have addressed the INTSORMIL objectives of increased yield and improved institutional capacity. Collaborating researchers in Ethiopia are working with farmers to address production constraints associated with water deficits and low soil fertility. Tillage and implement options are being tested at various semi-arid sorghum production areas in Ethiopia. Tillage effects on organic matter and soil physical properties are being assessed for improved soil water management. In eastern Nebraska, soil fertility management options are being evaluated including the use of starter fertilizers for no-till situations and the rotation effect of soybean on sorghum N nutrition. P availability indices are being fine-tuned for soils of Nebraska, Ethiopia and Mozambique.

An INIA researcher from Mozambique has started his Master's degree program on soil fertility management at the University of Nebraska. Two researchers are being recruited for Master's degree studies at Alemaya University in Ethiopia.

Objectives, Production and Utilization Constraints

- Initiate nutrient management and water conservation research, such as use of tie-ridging or micro-catchments, in two semi-arid areas in Ethiopia.
- Initiate on-farm trials and/or collaborate in on-going station trials to verify N credit to sorghum following soybeans.
- Begin research on starter fertilizers for no-till sorghum production in Nebraska.
- Initiate research to predict P fixation capacity of soils across Nebraska and Ethiopia and assess effect of tillage systems on organic matter and soil aggregation.
- Begin data compilation to evaluate internal nutrient use efficiencies, and relate variations in grain yield and seed number to plant N concentration, uptake, and N harvest index.
- Inadequate nutrient supply and water deficits are the primary production constraints addressed in this research.

Research Approach and Project Output

Work on each of the following was begun in 2002 and important findings are not yet available.

Nutrient and Water Management Research in Ethiopia

Preliminary research at three or four sites ranging in elevation from 1300 to 1800 m and with different soil types and cropping systems has been established in two semi-arid sorghum production areas of Ethiopia. The objectives are to obtain farmer and researcher assessment of tillage and implement options and to determine how tillage for water conservation interacts with nutrient supply and time of planting. The sites include Welench'iti, Mieso, and Mekele at Abergele with trials on three farms per site for both April and June planting. Main plot treatments include:

Traditional, e.g., tilled with *maresha*, broadcast sowing, and *shilishalo* for weed control.

In-furrow row planting with test planter and tie ridges made before planting with the modified *maresha*.

In-furrow row planting with test planter and tie ridges made at first weeding with the modified *maresha*.

Conservation tillage- reduced tillage. Plow 1-2 times. Apply Lasso Atrazine pre-emergence.

The split plot treatments are with and without fertilizer at the currently recommended rate. Farmer assessments of the technical options are considered as important as the agronomic observations.

Starter fertilizer for No-Till Sorghum Production in Nebraska

Starter fertilizer use has generally not been economical in Nebraska under tilled conditions. However, results from neighboring states indicate good potential for starter fertilizers under some no-till conditions. Starter placement, as well as inclusion of sulfur in the starter fertilizer, is being investigated under diverse no-till conditions to better determine when starter use will be economical. Three trials are conducted at different topographic positions/soil types on each of two farms with a total of 12 sorghum trials with 4 replications conducted over a 2-year period. All sites will be dryland. The eight treatments will include three placement options with the starter fertilizer formulations as either N+P or N+P+S. Observations are made on early growth and nutrient uptake, and on above-ground biomass and grain yield.

Soybean N credit Verified for Grain Sorghum

Currently a nitrogen credit of 45 lb/A is given to sorghum following soybean but the credit may be as much as 80 lb/A. The objective of this research is to verify a credit of 75 lb/A. Six on-farm trials have been established in Lancaster, Saunders and Gage counties across diverse topographic positions and soil types. All trials are under farmer management. Four N rates are evaluated with four replications per trial. Observations include days to flower, height, yield, and nutrient (N,P,K) uptake in whole plant and in grain.

P fixation

Phosphorus use efficiency will be improved by developing predictive methods for estimating P fixation capacity for soils of eastern Africa and Nebraska. Surface soil samples (0-15 cm depth) are being collected in Ethiopia, Mozambique and Nebraska. Phosphorus sorption indices are generated. Soil properties such as clay (texture), organic matter, calcium carbonate, and iron plus aluminum oxides levels will be related to P sorption indices for prediction of potential plant P availability and improved P recommendation.

Tillage and Organic Matter

Tillage effects on soil organic matter are being evaluated on soils from eastern African and Nebraska. The soil samples (0-5 cm depth) are collected from on-going tillage trials which have at least four years of continuous no-till as one treatment. Soils are sampled from the no-till as well as one or more tilled treatments. Tillage effects on organic matter fractions and aggregate stability are assessed.

Evaluation of Internal Nutrient Use Efficiency

Using data from trials conducted for other purposes and in diverse environments, internal nutrient use efficiency (uptake as well as metabolic use efficiency) by sorghum will be studied as a means to better understanding nutrient management for sorghum. It is expected that basic concepts of QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) will be useful in interpretation of the results. Data from several years and locations will be needed before conducting the analysis. Data compilation is underway.

Networking Activities

Technical and financial support, as well as equipment, has been provided to sorghum researchers in Ethiopia.

Publications and Presentations

Presentation

Soil and Water Management for Improving Sorghum Production, by Charles Wortmann and Martha Mamo presented to the Nebraska Sorghum Growers Board on June 11, 2002.