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 four-country development pilot program in the Sahel introduced not only new technologies but also new marketing strategies. The principal results from these activities were:

- Sahelian farmers appreciated the access to inorganic fertilizer and improved varieties of millet even though yield gains were modest due to the bad weather of 2001-2002. Farmers received input credit for millet production and were able to repay it if they received higher prices than those paid at harvest time.

- By waiting to sell their grain until prices recover approximately six months after harvest, farmers in Senegal and Mali received higher prices. In Mali there was also a price premium for quality, 10 FCFA/kg above market price, while in Senegal farmers were able to obtain 25 FCFA/kg above market price.

- In Niger, the market price went quickly above the contract price; therefore, most farmers sold their grain outside the contract. The government replenished public grain stocks. In the new contract for 2002-2003, the price-determination method has been changed to the market price at time of sale plus a quality premium (10 FCFA/kg). So there is a learning-by-doing effect from these market sales.

- Quality improvement is the next big challenge for helping processors and for increasing farm incomes. Currently, “baches” (rugs) are being introduced to keep the threshing off the ground, but this is only the first step. In Senegal (Kaolack region), some entrepreneurs are already offering threshing services for hire. Introduction of those threshing machines in other villages greatly improved the quality of grain. This is an objective of the Sasakawa 2000 project in 2003-2004.

Objectives, Production and Utilization Constraints

This year our principal activity was to collaborate in the four-country contracts between farmers and processors in the Sahel. Dr. John Sanders and Tahirou Abdoulaye spent October 2002 with Ouendeba Botorou and national food scientists in the field interviewing processors and farmers. This was a new activity for us, concentrating on marketing-strategy improvements to facilitate the introduction of new technologies in sorghum and millet production in an ongoing development program being implemented by three different NGOs in four Sahelian countries.

Besides this marketing activity, we continue to monitor the introduction of *Striga*-resistant cultivars in Ethiopia. We are analyzing technology and marketing innovations for maize and sorghum in Mozambique and we began a program to evaluate the introduction of N'Tenimissa with associated technologies in Mali.

Research Approach and Project Output

Marketing Strategies in the Four Country Sahelian Project. We have a four-point approach to increasing farmers' incomes with marketing strategies, thereby enabling them to utilize higher input levels, especially improved seeds and inorganic fertilizers. This strategy responds to the following four problems, reducing the price received by farmers:

1. *Post- harvest price collapse.* Farmers have very important cash requirements at harvest including debts acquired before and during the crop season, school fees, taxes, migration expenses, weddings, and naming ceremonies. The strategy is to enable farmers, as with inventory credit and storage, to avoid selling during the post-harvest price collapse period but to receive cash as an advance against the value of the harvest.

2. *Good-weather price collapse*. The basic problem is that people can only eat so much of the basic staples. With good weather, people consume up to the maximum they can afford and then prices collapse. The strategy is to develop new markets, as for processed cereals and ultimately feed grains as income growth continues, to dampen or eliminate the between-year price collapse in normal or good-rainfall seasons.

3. *Poor grain quality.* Processors are generally willing to pay more for a higher-quality, more uniform product. Farmers need sufficient bargaining power to pressure the processors to pay the quality premium. This works better where the processors are producing a high-value product, as the yogurt-producer in Senegal.

4. *Government/NGO intervention in bad weather year.* A principal poverty instrument in the Sahel is to keep food prices low to benefit the urban poor (and the influential middle-class, government bureaucracy). The strategy is to moderate or eliminate the response of public policymakers and NGOs in their efforts to drive down the prices received by farmers by introducing cheap grain.

The seasonal price variability is dramatic in the very dry years as prices during the year can more than double for the basic staple (Fig. 1). In a more normal rainfall year, as in 2002-2003, prices for Malian millet went from 110 CFA/kg at harvest to over 160 CFA in six months. Farmers rather than merchants need to benefit from this price variation so that the farmers can pay for the increased input costs of improved seeds and inorganic fertilizer. As many farmers delay more of their grain sales, the seasonal price variability will be reduced and ultimately eliminated.

A more long-range goal is to help develop markets for processed foods made from millet and sorghum. Note that substantial gains have been made by food scientists with rice and wheat, especially in reducing the processing and cooking time. Similar catch-up gains are now being made in sorghum and millet. As a consequence of technology availability in these cereals and increasing incomes, new products from millet and sorghum are rapidly being introduced into West Africa. These products are very important to urban women, who have much higher opportunity costs for their time than rural women. An important part of our field project is the food-scientist technical assistance from INTSORMIL directly to the rapidly expanding group of food processors involved in this four-country program.

As these new markets are developed the processors are expected to be willing to pay for a more uniform (one variety), higher-quality product. For example, much of the threshing of the basic cereals takes place on the ground, resulting in the

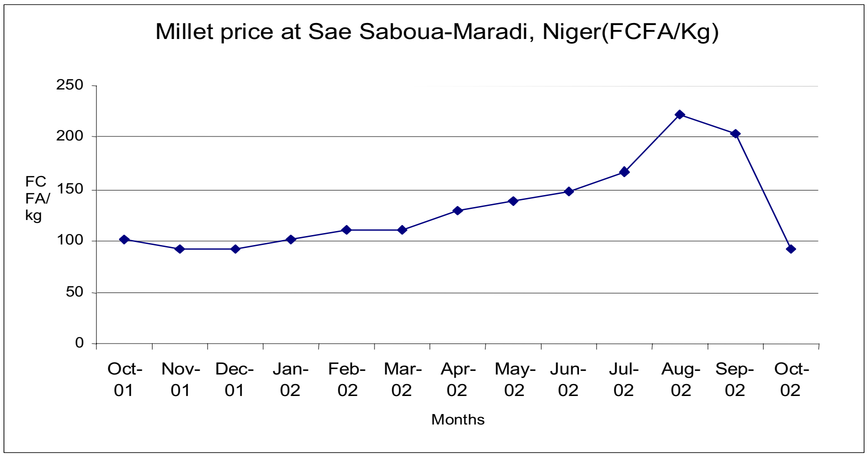

Figure 1. Farmer estimates of seasonal millet prices in the Maradi region of Niger for the crop year 2001-02
Source: Ouendeba et al., 2003.

inclusion of dirt and stones in the marketed grain. Women have to be hired by the processors to laboriously clean up the grain. Over time the processors are expected to be prepared to pay a quality premium for a higher-quality product and the easiest first innovation was to put the "bache" (rug) under the grain for the threshing. In the future, there is expected to be a high return for introducing mechanical threshers in the village.

The final change (4 above) may be the most important and also the most difficult. Most Sahelian governments act as if the only available poverty policy is to keep the prices of food staples low. NGOs reinforce this behavior by dumping food staples from developed countries. Both thus reduce the profitability of agricultural production and discourage farmers from using inputs or making investments in agriculture. There are other poverty policies besides depressing the agricultural sector. For example, NGOs could buy food staples from the higher-rainfall regions of developing countries in adverse climatic years and then use these staples in Food for Work programs in the low-rainfall regions in the same country.

In the long run, technological change will gradually reduce the costs of output, enabling food staple prices to decline while farmers (and consumers) still benefit. Some farmers can benefit from costs falling faster than prices. However, in the short run, it is important to avoid the food-price collapses from the combination of good weather and technological change. Moreover, avoiding the government- and NGO-induced distortions of driving down the profitability of agriculture in adverse climate years is also important.

Do these different strategies make a difference by enabling farmers to pay for the necessary inputs to modernize their agriculture? Figure 2 illustrates the ability of farmers to pay off the costs of improved seeds and fertilizer. The break-even point for paying for inputs with no quality premium is almost at 150 CFA/kg. With a 10 CFA price premium the break-even point is 115 CFA. With a 20 CFA/kg premium for quality, farmers can even make a small profit selling at the harvest price of 80 CFA/kg. Many processors are now prepared to pay a 10 CFA premium for keeping the rocks and dirt out of the millet. Further quality improvements are also feasible.

How well did the contact program between farmers and processors function in the first year of activity 2001-2002 in increasing the incomes of farmers? 2002 was a very dry year and yields were way down. Of the last six years in Mali 1997-1999 were good, 2000-2001 normal and this year bad. With yields down, quantities of millet and sorghum available for sale were generally below what farmers had contracted with the processors.

In Senegal and Burkina Faso, processors refused to buy at the higher prices requested after harvest and with a quality premium, so the NGOs coordinating this program, EWA and SG 2000, became the buyers. They gave good prices and repayment rates were high. There is a process between processors and farmers of learning about bargaining power. In the past, the processors, being more limited in number and communicating among themselves, had most of the market power. Now this begins to change as farmers organize into producers' associations with the help of these NGOs.

In both Senegal and Niger, the yield effects of new technologies were very important in increasing incomes (Table 1). Farmers are generally recognizing the need to buy inputs even with the poorer responses of the dry year. There is an awareness of the loss of soil fertility with higher population densities and the inadequacy of organic fertilizer. Fertilizer prices have been increasing so the importance of getting a good price for

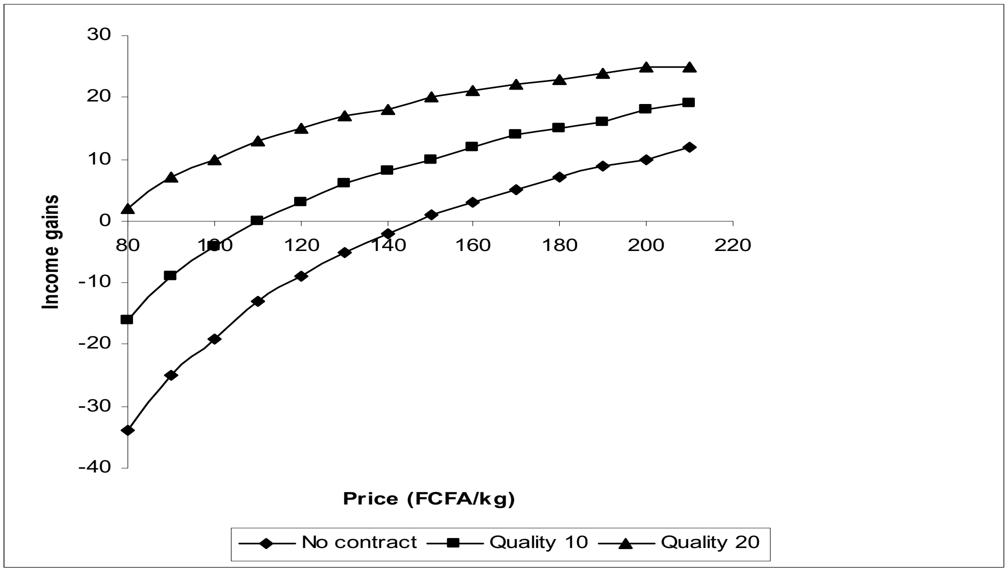

Figure 2. Income gains for participating farmers for three pricing scenarios, Kondogol, Mali, 2003
Source: Ouendeba et al., 2003.

Table 1. Per-hectare income gains[1] from the contract program in the three countries

	Niger	Mali	Senegal
Yield effect	11%	4%	16%
Price effect	2%	21%	11%
Total effect	13%	23%	27%

[1] Using harvest-time price from field interviews in the four-country development project.
Source: Estimated from the field interviews in the four country development project.

millet/sorghum is becoming generally recognized. This is the main focus of the program.

In Niger and Mali, active governmental intervention by importing food staples affected prices. In Niger, there has been purchasing to add to public cereal stocks, thereby driving prices upward and causing farmers to lose interest in the contract price. In Mali with the bad weather, the government and NGOs have been importing grains and driving down the sorghum/millet price after June 2003 but well before the next harvest.

In Senegal, EWA bought 12 tons of millet at CFA and then sold it to the yogurt producer for 200 CFA/kg. Of the various processors, EWA had the best understanding of the bargaining-power problem. Apparently farmers will need the interventions of these NGOs until they learn how to negotiate for their share. The price effect was the dominant effect in Mali and also very important in Senegal (Table 1).

Our first objedctive in this program is to enable farmers to increase their bargaining power and to get higher prices so they can afford to pay more for inputs. Farmers need to purchase fertilizer and improved cultivars since their soils have been mined of nutrients and new cultivars are needed to take advantage of higher input conditions.

But an important secondary purpose of this activity is to assure the supply to the processors and obtain for them a higher-quality product. The first requirement on the quality side is farmer utilization of a uniform and higher-quality variety and secondly to avoid threshing on the ground. Threshing techiques vary and the simplest improvement is to put a "bache" (sheet or rug) down on the ground. Then threshing can be done with sticks or by driving over the bache. Clearly the next technical improvement needs to be threshing machines at the farm level.

Shifts in Demand with the Rapid Growth of the Poultry Industry in Central America. The most significant shift in demand for sorghum is the structural change in diets as incomes grow. Consumers reduce their consumption of the basic grains (or in higher-rainfall regions, tubers) and consume higher levels of animal products (meat, milk, and cheese), fruits, and vegetables. Poultry consumption increases exponentially as production and consumption technology shifts result in rapid declines of the price of poultry relative to other meats. These changes continue for decades and are still going on in the US. Central America is well into these changes in consumption patterns (Fig. 3). For sorghum producers in Central America, this implies the need to compete with maize imports and domestic maize production. Both El Salvador and Nicaragua have been implementing policies for their sorghum producers to benefit from these demand shifts. We are studying the interaction between marketing strategies and the introduction of new technologies by sorghum producers in both El Salvador and Nicaragua.

Technology-Marketing Evaluation in Mozambique and Mali. In Mozambique during the winter of 2003, Rafael Uaiene spent three months in the field interviewing maize/sorghum producers in one of the principal zones of agricultural production in the country. He is presently analyzing the data for the comparison and contrast of the process of technological change-marketing strategy for maize and sorghum. An important component of this activity is the development of new markets through product processing of these two crops.

Dr. Sanders and Tahirou Abdoulaye spent two weeks with Ouendeba Botorou and Aboubacar Traore interviewing farmers and processors about the introduction of N'Tenimissa and progeny in Mali. Yigezu will be following up this activity, doing field surveying and then his analysis for his M.S. degree beginning in the fall of 2003.

Networking Activity

Dr. Sanders participated in the *Striga*-resistant sorghum and associated technologies workshop organized by Dr. Gebisa Ejeta in Nazareth, Ethiopia in November 2002. He presented a paper there with Nega Wubeneh's results from the introduction of *Striga*-resistant sorghums and associated technologies in Tigray, Ethiopia and interacted with participants.He began the planning for a more thorough evaluation of the introduction of the *Striga*-resistant sorghums and associated technologies in Ethiopia in 2004.

Dr. Sanders and Kidane Georgis presented a summary of their results from the six-country Horn study for IGAD in the PI Meeting of INTSORMIL researchers and collaborators in

Addis Ababa, Ethiopia in November 2002. Dr. Sanders also presented a paper at this same meeting, laying out the marketing strategy and the preliminary results from the four-country Sahelian project.

In July and August 2002, Amare Belay from the Tigray regional research station in Mekelle and Kidane Georgis, the Director of the Dryland Research Program in EARO (the Ethiopian Agricultural Research Organization) in Addis Ababa came to Purdue University to collaborate with us. Amare Belay was here for three weeks and Kidane Georgis for two months. This travel, per diem, and consulting fees were paid by Dr. Gebisa Ejeta's regional budget for the Horn of Africa.

Publications and Presentations

Publications

Abdoulaye, Tahirou, and J.H. Sanders. 2002. "Farm-Level Profitability and Evolution of Iput-Output Markets: Economic Perspective." In Proceedings, *West African Hybrid Sorghum and Pearl Millet Seed Workshop,* Sept. 28 - Oct. 2, 1998, Niamey, Niger. Lincoln, NE: INTSORMIL, Publication No. 0202, April 2002.

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Sanders, J. H. and B. I. Shapiro, 2003. "Crop Technology Introduction in Semiarid West Africa: Performance and Future Strategy." In Anil Shrestha (ed.), *Cropping Systems:Trends and Advances.* Binghamton, NY: Haworth Press, Inc.

Thesis

Wubeneh, Nega. "Farm-Level Adoption of New Sorghum Technologies in Tigray Region, Ethiopia," M.Sc., Purdue University, Dept. of Agricultural Economics, May 2003.

Presentations

Ouendeba, B., Abdoulaye, T. and Sanders, J. H., "Food Staples in West Africa: Production and Marketing," Paper presented at the Ethiopian meeting of the INTSORMIL PIs, Addis Ababa, Nov. 2002.

Sanders, J. H., and Georgis, K., "Applications of the Results from the Six-Country IGAD Study on New Technology Introduction into the Drylands to the INTSORMIL Program," paper presented at the Ethiopian meeting of the INTSORMIL PIs, Addis Ababa, Nov. 2002.

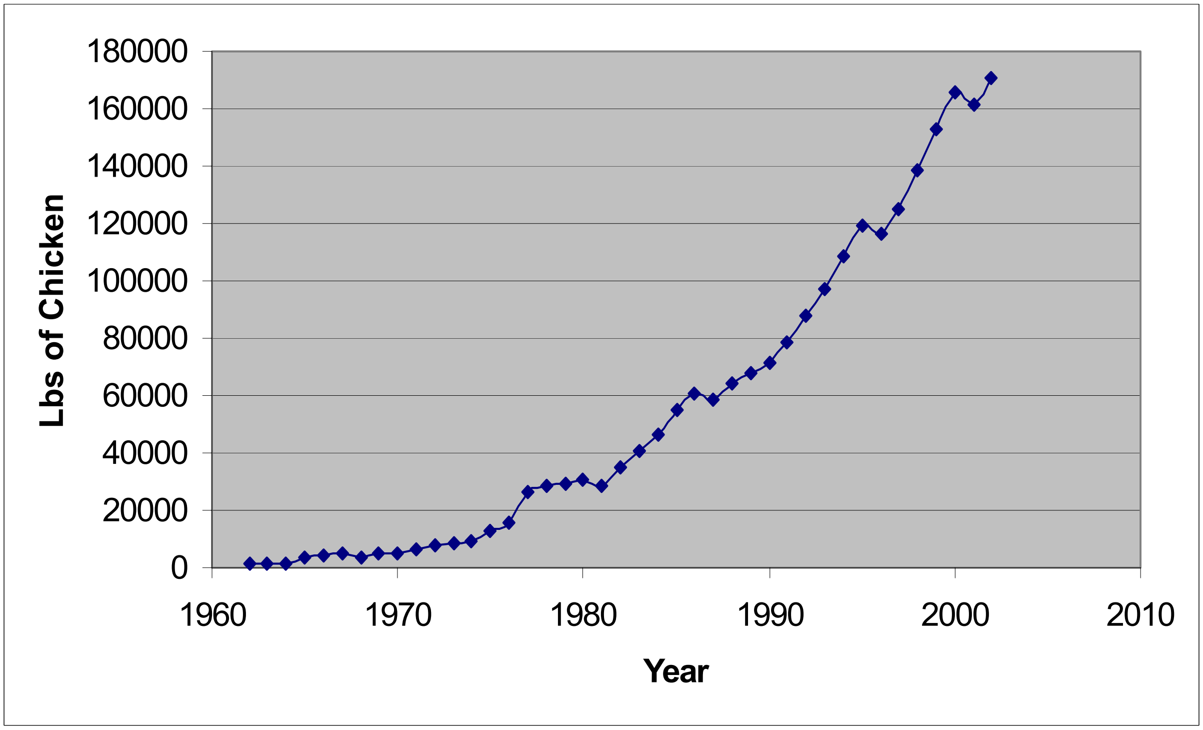

Figure 3. Growth of poultry production in El Salvador, 1962-2002
Source: Unpublished data from Aves (Chicken Producers' Association in El Salvador).

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

Project UNL 213

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Summary

Principle 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 microdose fertilizer application responses in West Africa have increased pearl millet grain (35%) and stover (56%) yields, but the results are variable across locations. Highest grain and stover yields have been produced with application of 20 kg ha^{-1} P and 30 kg ha^{-1} N which more closely matches the nutrient extraction by the crop. Research showed that an animal traction zai system produced similar yield to the traditional zai system across six different soil textures in Burkina Faso, but while only requiring 22 man-hours 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 photoinsensitive sorghum varieties. Nitrogen application of 90 to 115 kg ha^{-1} was necessary to optimize grain yields. In El Salvador, the photoperiod sensitive varieties SCP-805 and ES-790 for relay intercropping with maize were found to be high yielding and to have high NUE and % N Fertilizer Recovery. Grain yields were optimized with 47 kg ha^{-1} N application. Validation trials are underway on-farm in collaboration with non-governmental agencies to promote the use of the variety SCP-805 with moderate application of nitrogen fertilizer.

Research in the United States indicates that kernel weight is the most important yield component to explain yield variation across environments for pearl millet and grain, and therefore, merits more attention in plant breeding and crop management research. Crop rotation was shown to have economic advantages due to diversification benefits in addition to enhanced yields, reduced costs and greater yield stability. 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 dryland production on high water holding capacity soils in the western corn belt. 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 Region Program. A graduate student from Niger completed a Ph.D. degree, and students from Chad and the U.S. are working on M.S. degrees.

Objectives, Production and Utilization Constraints

Objectives

- Conduct 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.
- Conduct research on mechanized zai 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.
- 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 to better understand the shift of dryland sorghum area to maize in the Western Corn Belt.
- Determine recommended production practices for pearl millet production in Nebraska.
- Conduct N rate and N use efficiency studies for grain sorghum production in El Salvador and Nicaragua to identify N use efficient varieties and determine N rate recommendations.
- Increase research human capital in West African countries where pearl millet is an important crop through graduate education, short-term training and through mentoring former students upon return to their home country.
- Collaborate with national extension services and NGO/PVOs in transferring improved pearl millet and grain sorghum 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 inorganic and organic fertilizer management, developing varieties and cropping systems to improve nitrogen use efficiency of sorghum, water management of traditional and improved cultivars, and weed control strategies. Cropping system research efforts require long-term investments of well-trained, interested scientists and stable funding. Education of additional scientists in crop management 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 as graduate education programs for scientists from this region and as mentored collaborative activities upon return of former graduate students. Studies have been initiated with collaborators in Central America on nitrogen fertilizer management and identification of nitrogen use 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 pearl millet 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 213's research efforts.

Domestic (Nebraska)

Environment Effect on Pearl Millet and Grain Sorghum Yield Components (Nouri Maman, Ph.D. Thesis)

Research Methods

The experiment was conducted on a Keith silt loam under a linear move irrigation system with drop nozzles at the High Plains Agricultural Laboratory located at Sidney in western Nebraska (semi-arid environment) 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 (68Ax 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. Environments were considered to by year, location and water regime combinations. Grain and the yield components of panicles m^{-2}, kernels panicle-1 and kernel weight were determined at harvest and corrected to 14% water content. A similar study was conducted in eastern Nebraska at Mead (sub-humid environment) using a furrow irrigation system. Data were analyzed using analysis of variance and path correlation procedures.

Research Results

At Sidney no rainfall occurred during the 2000 growing season, thus low average (across water regimes) grain yields of 1.9 Mg ha^{-1} for pearl millet and 4.1 Mg ha^{-1} for grain sorghum were produced. In 2001, Sidney produced higher average yields of 3.9 Mg ha^{-1} for pearl millet and 5.0 Mg ha^{-1} for grain sorghum with good rainfall, and in Mead in both years the average grain yields were 5.1 Mg ha^{-1} for pearl millet and 6.1 Mg ha^{-1} for grain sorghum. The higher yields at Mead than at Sidney was the result of higher soil water holding capacity and a less stressful production environment.

In the semi-arid, non-irrigated environment at Sidney, all yield components were positively correlated with pearl millet and grain sorghum grain yield = 0.87 to 0.99), but due to the greater direct effect, kernel weight (p = 0.46) and panicles m^{-1} (p = 0.80) were the major contributors to yield (Table 1). In the sub-humid environment at Mead, kernel weight was the major contributor for pearl millet grain yield with a positive correlation = 0.81) and greatest direct effect (p = 0.77). Yield increase with irrigation in the semi-arid environment in western Nebraska resulted from increased panicles m^{-2}, kernels panicle $^{-1}$, and kernel weight for both crops. Yield increase in the sub-humid climate in eastern Nebraska with irrigation for pearl millet was mostly due to an increased kernels panicle^{-1}. Kernel weight, with greater positive correlation (r = 0.64 to 0.99) and greater direct effect (p = 0.40 to 0.98), was the major yield contributor for both crops in all sub-humid environments. In all sub-humid environments, except for grain sorghum panicles m^{-2} with no irrigation, kernel weight was the most important yield component for pearl millet and grain sorghum. It was concluded that

Table 1. Path analysis direct effects (underlined and bold) and indirect effects of number of panicles m^{-2}, kernel weight, and number of kernels per panicle of pearl millet and grain sorghum as affected by water regimes in 2000 and 2001 at Sidney, NE.

	Pearl millet				**Grain sorghum**			
	Panicles m^{-2}	Kernel weight	Kernel panicle^{-1}	r	Panicles m^{-2}	Kernel weight	Kernel panicle^{-1}	r
All water regimes								
Panicles m^{-2}	**0.16**	0.04	0.14	0.34	**0.17**	0.53	0.10	0.80
Kernel weight	0.01	**0.46**	0.41	0.87	0.14	**0.65**	0.07	0.86
Kernels panicle^{-1}	0.05	0.42	**0.45**	0.93	0.08	0.21	**0.21**	0.51
No-irrigation								
Panicles m^{-2}	**0.25**	0.38	0.30	0.92	**0.80**	0.35	-0.16	0.99
Kernel weight	0.20	**0.46**	0.31	0.97	0.76	**0.37**	-0.16	0.97
Kernels panicle^{-1}	0.23	0.43	**0.33**	0.98	0.72	0.33	**-0.18**	0.87
Boot irrigation								
Panicles m^{-2}	**0.19**	-0.75	-0.22	-0.78	**-0.12**	0.70	-0.06	0.52
Kernel weight	-0.16	**0.89**	0.26	0.99	-0.10	**0.88**	-0.15	0.63
Kernels panicle^{-1}	-0.15	0.86	**0.27**	0.98	0.02	-0.30	**0.46**	0.18
Mid-grain fill irrigation								
Panicles m^{-2}	**0.02**	-0.12	-0.05	-0.15	**-0.09**	0.81	0.01	0.73
Kernel weight	-0.004	**0.68**	0.32	0.99	-0.07	**0.98**	-0.08	0.83
Kernels panicle^{-1}	-0.003	0.65	**0.33**	0.98	0.002	-0.34	**0.22**	-0.12
Multiple irrigation								
Panicles m^{-2}	**0.27**	-0.49	0.19	-0.41	**0.01**	0.41	-0.10	0.31
Kernel weight	-0.22	**0.61**	0.40	0.79	0.001	**0.96**	-0.07	0.90
Kernels panicle^{-1}	-0.12	0.54	**0.46**	0.88	-0.002	0.22	**0.29**	0.07

plant breeding and crop management research to increase pearl millet and grain sorghum yield should increase emphasis on kernel weight.

Impact of Crop Rotation on Risk (Nouri Maman, Ph.D. Thesis)

Research Methods

To isolate the risk contribution to income stability from crop rotations, an analysis of two eastern Nebraska dryland rotation studies was done. One was a corn-soybean rotation with data from 1985 to 1998 and the second, a grain sorghum - soybean rotation study with data from 1981 to 1996. Historic yield, estimated operating expenses and grain price data were used to calculate net returns for continuous corn (or grain sorghum), continuous soybean, diversification without crop rotation, and rotational cropping systems. The four cropping systems were evaluated for average net returns and risk. Risk was calculated as the standard deviation of net returns (measure of stability of net returns) and totaling the dollar deficits for all years where net returns fell below $100 per acre.

Research Results

In the corn-soybean study the standard deviation of net return was $64 for continuous corn, $51 for continuous soybean, $46 for the diversification system, and $57 for the rotation which was basically mean of the two continuous systems. In this study, the net return variability was greater for the rotation system than for the diversification system, thus crop rotation reduced stability of crop yields. In contrast, in the grain sorghum-soybean study the standard deviation was $67 for continuous grain sorghum, $52 for continuous soybean of, $41 for diversification, and $40 for the rotation. In this study crop rotation increased average net returns, and both crop rotation and diversification systems reduced return variability. For both experiments, the rotations reduced risk in terms of net returns meeting a target return. This was due to the increased yield and reduced cost associated with use of crop rotation rather than continuous cropping.

Crop rotation exhibited potential economic advantages over continuous cropping. The was partially due to diversification (i.e., more than one crop being present in an individual year), but was also influenced by enhanced yields, reduced costs, and the potential increase in yield stability. The latter was much more evident in the grain sorghum-soybean study than the corn-soybean study.

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 as the best performing hybrids in the University of Nebraska Performance Tests and they were produced in three environments each year. The environments were sandy loam and silty clay loam soil types, and irrigated and dryland water regimes on the silty clay loam soil. Regression analysis was conducted to relate year of hybrid release to yield with the objective to determine if a difference in rate of yield increase was present between maize and grain sorghum for different production environments.

Research Results

Maize yields were higher than grain sorghum for all production environments and hybrids (Fig. 1). On the high water holding capacity silty clay loam soil, irrigation increased maize

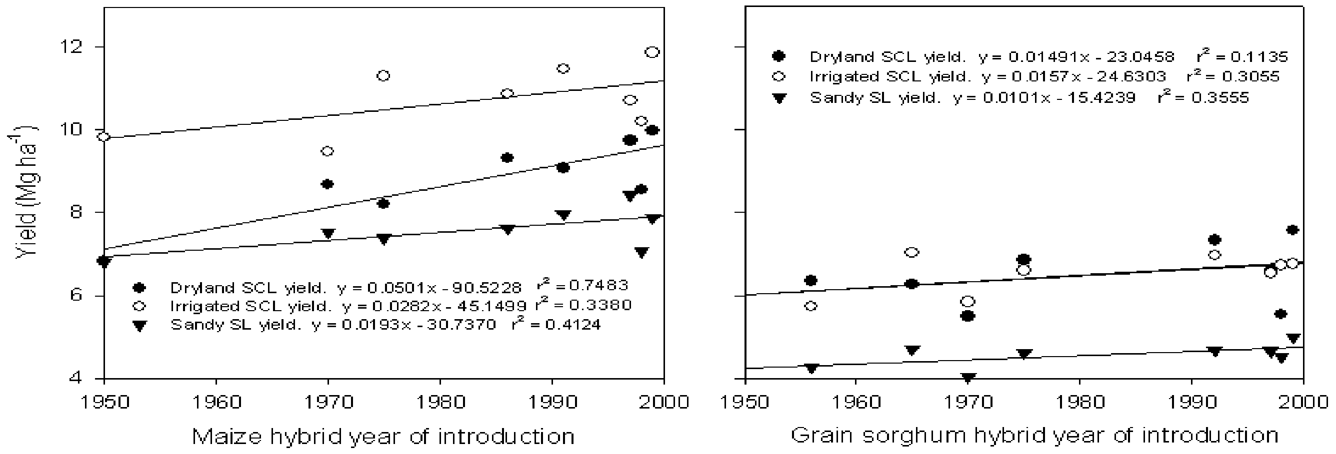

Fig. 1. Grain sorghum and maize grain yield as influenced by year of introduction for dryland silty clay loam soil, irrigated silty clay loam soil and dryland sandy loam soil environments, 1999 - 2001.

grain yield but not for grain sorghum. The rate of yield increase was similar for maize in the sandy loam soils, and grain sorghum in all production environments with the rate of increase being 0.05 ± 0.004 Mg ha^{-1} yr^{-1}. The rate of increase for irrigated maize was 0.0282 Mg ha^{-1} (28 kg ha^{-1}) and 0.0501 Mg ha^{-1} (50 kg ha^{-1}) for dryland maize produced in the high water holding capacity silty clay loam soil. These rates of maize yield increase, except for the dryland, high soil water holding capacity soil, are considerably lower than the 57 to 89 kg ha^{-1} yr^{-1} reported in the literature for dryland production in central Iowa (Duvick and Cassman. 1999. Crop Sci.39:1622 - 1630). This suggests that the ability to tolerate intermediate stress likely to occur in dryland production on high water holding capacity soils has been the major contribution of plant breeding to maize yield improvement in eastern Nebraska during the past 50 years. These rates of sorghum yield increase due to hybrid improvement are also less than the 23 kg ha^{-1} yr^{-1} reported in the literature for Bushland, Texas (Unger and Baumhardt. 1999. Agron. J. 91: 870 - 875). The higher yields and higher rate of yield improvement of maize on dryland, high soil water holding capacity soils partially explain the replacement of dryland grain sorghum with dryland maize in the western corn belt during the last 10 years.

International

Microdose Fertilizer Study
(Taonda Jean-Baptiste - Burkina Faso, Minamba Bagayoko and Samba Traoré -Mali, and Seyni Sirifi - Niger)

Research Methods

Three-year central studies were initiated on-station in Burkina Faso (pearl millet), Mali (pearl millet on sandy 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 (capfull 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 kg ha^{-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 or 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. However, on the average, microdose fertilizer application increased grain and stover yield by 35 to 61% on-station and on-farm (Tables 2 and 3). Clearly the microdose application is a low cost investment that has a high probability to increase grain yields across the West Africa pearl millet production area. On-station studies indicated that to maximize grain and stover yields required application of 20 kg ha^{-1} P and 30 kg ha^{-1} N in addition to the microdose application. A related study on grain sorghum in Burkina Faso in 2002 had a grain yield increase from 1.4 to 2.2 Mg ha^{-1} Earlier research (Bagayoko et al., 2000, J. Agric. Sci. 135: 399 - 407; Bagayoko et al., 2000, Plant Soil 128: 103 - 116)) indicated that P application and crop rotation with cowpea increased early season root growth leading to greater exploration of the soil profile for nutrients and increased early endomyccorhizal infections, thus stimulating plant growth and nutrient uptake. This increase in grain and stover yield removes more N and P than is applied with the microdose application, so may actually contribute to more rapid depletion of soil nutrients in these soils. One goal of this research is to continue these long-term studies to determine whether more rapid nutrient depletion occurs or not.

Weed Control X Fertilizer Study
(Samba Traoré - Mali)

Research Methods

A randomized complete block designed experiment to evaluate the interactive effects of hand weeding method and fertilizer application on pearl millet grain and stover yield was conducted at the Cinzana Research Station in 2001 and 2002. Pearl millet was hill planted on ridges after fertilizer application. Hills were thinned after emergence to two plants per hill. Fertilizer treatments consisted of microdose (2 grams diammonium phosphate per hill), 6 grams of 15-15-15 per hill, and 4 T ha^{-1} manure incorporated during soil preparation plus 50 kg ha^{-1} diammonium phosphate broadcast applied after emergence. Mechanical weed control treatments consisted of complete control, weeding of ridges only, and no weeding. Grain and stover yield were determined, and data were analyzed using analysis of variance procedures.

Research Results

Analysis of variance indicated that yield differences were due to year X weed control and year X fertilizer treatments. No weed control X fertilizer interaction effects were present. In both years, rainfall was limited late in the growing season resulting in average grain yields of 800 to 900 kg ha^{-1}, and average stover yields of 3344 kg ha^{-1} in 2001 and 1635 kg ha^{-1} in 2002. Weed competition was much greater in 2002 than 2001, at least partially accounting for the lower stover production in 2002. In 2001 with low weed pressure present, mechanical weeding treatments had little effect on grain and stover yield, while in 2002 weeding of ridges increased grain yield by 470 kg ha^{-1} (93%) and complete weed control increased grain yield

Table 2. On-station mean pearl millet grain and stover yield as influenced by fertilizer treatment in West Africa. Values represent mean of location (Burkina Faso, Mali and Niger), year (2001 and 2002) and soil type (sandy and loam) in Mali.

	Grain			Stover		
Fertilizer Treatment	Mean	Range	Increase	Mean	Range	Increase
	---------- Mg ha^{-1} ----------		%	---------- Mg ha^{-1} ----------		%
Zero	0.46	0.11 to 0.88		1.6	0.5 to 4.1	
Microdose	0.62	0.34 to 1.10	35	2.5	1.1 to 6.3	56
Microdose + 20 kg ha^{-1} P	0.77	0.24 to 1.23	67	3.1	1.4 to 6.8	94
Microdose + 40 kg ha^{-1} P	0.81	0.46 to 1.40	76	2.9	1.2 to 5.3	81
Microdose + 30 kg ha^{-1} N	0.69	0.37 to 0.95	50	3.0	1.2 to 8.6	88
Microdose + 60 kg ha^{-1} PN	0.71	0.38 to 1.12	54	3.0	1.2 to 8.8	88
Microdose + 20 kg ha^{-1} P + 30 kg ha^{-1} N	0.97	0.60 to 1.33	111	3.7	1.5 to 8.4	131
Microdose + 20 kg ha^{-1} P + 30 kg ha^{-1} N	0.85	0.35 to 1.29	85	3.7	1.8 to 8.4	131

Table 3. On-farm mean pearl millet and sorghum grain and stover yield as influenced by fertilizer treatment in West Africa. Values represent means of locations (Burkina Faso, Mali and Niger) and year (2001 and 2002).

	Grain			Stover		
Fertilizer Treatment	Mean	Range	Increase	Mean	Range	Increase
	-------- Mg ha^{-1} -------		%	------- Mg ha^{-1} --------		%
Zero	0.44	0.27 to 1.00		2.4	0.4 to 5.9	
Microdose	0.71	0.33 to 1.43	61	3.8	1.1 to 7.9	58

by 736 kg ha^{-1} (146%). The application of 6 gram diammonium phosphate did not increase grain or stover yield due to salt injury reducing emergence. The manure + 50 kg ha^{-1} diammonium phosphate treatment did not increase grain yields greatly in 2001, but in 2002 increased grain yields by 912 kg ha^{-1} (150%) over the microdose treatment. Climatic factors make it difficult to draw concrete conclusions from these two years results.

Mechanized (Animal Traction) ZaV Research
(Taonda Jean Baptiste - Burkina Faso)

Research Methods

The traditional zaV system composed of planting pearl millet seed in a small hole with a small amount of manure which increases water infiltration on some soils and results in increased yield, but requires considerable land labor. Scientists at INERA have developed a mechanized zai using animal traction. The objective of this study was to determine the effectiveness of the mechanized zaV (with 300 g compost per hill) to the traditional zaV (with 300 g compost per hill) and a flat-planted control (without compost) across six different soil types (textures) in Burkina Faso. The study was conducted on 12 farms in the villages of Saria, Nandiala and Kindi in a 800 mm yr^{-1} rainfall zone. Each farm considered a replication. The soil types present on the farms was sandy (2 farms), sandy loam (5 farms), sandy clay (5 farms), clay (2 farms), gravelly clay (4 farms) and gravelly (6 farms).

Research Results

Pearl millet grain yields varied across soil types with control yields ranging from 246 to 686 kg ha^{-1} (Table 4). The use of the zaV or mechanized zaV consistently increased yields, with the yield increase being greatest on the gravelly soil. Pearl millet stover yield was increased by a similar magnitude. The combination of tillage, creation of a micro-catchment to increase water infiltration, and compost application certainly increased crop yield, and the human labor savings of approximately 278 man-hours ha^{-1} suggest that this is a viable technology for Burkina Faso production situations. The economics of adoption ultimately must include the cost and maintenance of the traction animal and equipment, and of the compost. A complete economic analysis is being conducted, with intent to actively promote transfer of this technology to producers.

Table 4. Planting system influence on pearl millet grain yield across soil types in Burkina Faso, 2001 - 2002.

	Soil Texture						
Planting System	Sandy	Sandy Loam	Sandy Clay	Clay	Gravelly Clay	Gravelly	Mean
	-------------------------------- kg ha^{-1} (% increase) ---------------------------------						
Control (Flat)	457	246	473	686	492	289	441
Zaï	824 (80%)	433 (76%)	763 (61%)	1189 (73%)	824 (67%)	830 (187%)	811 (84%)
Mecanized Zaï	1032 (125%)	573 (133%)	787 (66%)	1111 (62%)	1003 (104%)	852 (195%)	893 (102%)

Production Practices for Hybrid Sorghum Seed Production

(Seyni Sirifi - Niger)

Research Methods

A study was conducted in Lossa, Niger in 2001 and 2002 to determine recommended plant populations and nitrogen application rates for seed production of the sorghum hybrids NAD1 and F221. The experimental design was a randomized complete block with split plot treatment arrangement and three replications. Whole plots were four rows of the female inbred lines of Tx623A for NAD1 and 221A for F221 with a row of the male parent MR 732 on both sides. The sub-plots were a factorial combination of four plant populations (15,625; 20,833; 31,250; and 62,500 plants ha^{-1}) and four nitrogen rates (0, 22, 44 and 66 kg ha^{-1} as urea). were planted planted at four plant populations and four nitrogen rates. Date of flowering, plant height and seed yield data was collected.

Research Results

In 2002, seed was not produced due to nicking problems between male and female plants, and the yields were very low in 2001 ranging from 41 to 452 kg ha^{-1}. In general, the best yields were produced with a plant population of 31,250 plants ha^{-1} in combination with 66 kg ha^{-1} N. Crop conditions at the Lossa Station for planting time and supplemental irrigation are critical to justify hybrid seed production at this location.

Nitrogen Use Efficiency (NUE) of Photoperiod Insensitive Sorghum Varieties

(Wilfredo CastaZeda, Leonardo García and Orlando Téllez - El Salvador and Nicaragua)

Research Methods

A three-year study was conducted at two locations in El Salvador and two locations in 2002-2003 in Nicaragua, and in 2002-2003 in El Salvador with the objective to determine if NUE differences exist among photoperiod insensitive sorghum varieties and optimal N fertilizer rates for grain sorghum production, and to identify high NUE varieties. At each location a factorial combination of four grain sorghum varieties were grown with four N 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 NUE. Data analysis was done using analysis of variance procedures, and orthogonal contrasts determined for N rate response. In 2002, 24 lines from the breeding program were grown with out N and with 112 kg ha^{-1} N, and evaluated for grain and stover yield, percentage N, and NUE in Nicaragua. These same breeding lines were evaluated for grain and stover yield, and agronomic characteristics in El Salvador and Nicaragua.

Research Results

Among the photoperiod insensitive varieties only small differences in grain, biomass and fertilizer nitrogen use efficiency were found, 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. This research was initiated in 2002, and the lines ICSVLM-90510, ICSVLM-90520 and ICSVLM-89513, look promising based upon grain and stover yield without and with fertilizer N application, and agronomic conditions in both El Salvador and Nicaragua.

Grain sorghum yields usually responded to increasing N application rates in a quadratic manner, and yield maximized occurred with 90+ (Nicaragua) to 115 kg ha^{-1} by the highest rate used in either El Salvador or Nicaragua. In El Salvador, 115 kg ha^{-1} nitrogen increased average grain yield of photoperiod insensitive sorghum varieties from 2.5 to 4.5 Mg ha^{-1} in both years, while 90 kg ha^{-1} nitrogen in Nicaragua increased average grain yield from 1.7 to 3.6 Mg ha^{-1}. These impressive yield increases resulting from N application and economic analyses indicate that producers should increase N application rates to 90 to 115 kg ha^{-1} N to optimize economic return.

Nitrogen Use Efficiency (NUE) of Photoperiod Sensitive (Maicillo Criollos) Sorghum Varieties for Relay Intercropping with Maize

(Wilfredo CastaZeda - El Salvador)

Research Methods

A two-year study was conducted at Santa Cruz Porillo and Izalco in El Salvador in 2002-2003 with the objective to determine if NUE differences exist among photoperiod sensitive sorghum varieties and optimal N fertilizer rates for grain sorghum production, and to identify high NUE varieties. At each location a factorial combination of six grain sorghum varieties were grown with N fertilizer rates of zero, 47, 95 and 142 kg ha^{-1} in a randomized complete block design with four replications. Grain and stover yield, and N concentration of grain and stover at harvest were collected to allow determination of NUE. Data analysis was done using analysis of variance procedures, and orthogonal contrasts to determine the N rate response.

Results

Across the four location-year combinations, the photoperiod sensitive varieties SCP-805 and ES-790 produced the highest grain yield and grain nitrogen use efficiency, and had high % N fertilizer recovery at both low and high N rates (Table 5). ES-790 had very high % N fertilizer recovery at the 47 kg ha^{-1} N rate, but SCP-805 had slightly higher yield, NUE and % N Fertilizer Recovery at high N rates. The varieties Santa Cruz,

Table 5. Yield and NUE differences among photoperiod sensitive (Maicillo Criollo) varieties in El Salvador, 2002 - 2003.

	Yield		NUE		N Fertilizer Recovery		
Variety	Grain	Stover	Grain	Biomass	47 kg ha^{-1} N applied	95 kg ha^{-1} N applied	142 kg ha^{-1} N applied
	---- Mg ha^{-1} ----		kg grain(biomass) kg^{-1} N		------------------------------ % ------------------------------		
SCP-805	4.1	6.1	59	136	50	51	44
ES-790	3.9	6.3	55	138	74	46	37
86-EO-226	3.3	5.6	47	131	10	24	17
Limay	3.1	7.6	42	143	42	40	30
Santa Cruz	1.6	7.7	25	140	40	60	33
Yalaguina	1.4	6.9	25	138	33	27	19

Limay and Yalaguina had higher stover and lower grain yield than the other varieties. The variety 86-EO-226 had high NUE, but low % N Fertilizer Recovery suggesting that it efficiently uses N within the plant, but has low ability to take up N from the soil. The variety SCP-805 is being validated on-farms with and without N fertilizer application in collaboration with several Non-Governmental Organizations (NGOs) during the 2003 growing season.

Photoperiod sensitive varieties were selected under low soil N conditions since these producers are poor and seldom apply N to sorghum. Averaged across varieties, yields increased quadratically with increasing N rate. Although the highest yield was produced at the highest N rate, 47 kg ha^{-1} N was the most economical and produced the highest NUE and % N Fertilizer Recovery. Application of 47 kg ha^{-1} N increased grain yield from 2.1 to 3.0 Mg ha^{-1} and stover yield from 5.0 to 7.1 Mg ha^{-1}. It was concluded that relatively low N rate applications should be recommended to producers of Maicillo Criollo sorghum varieties.

Networking Activities

Workshops

INTSORMIL Central America Regional Research Directors Meeting. Managua, Nicaragua, 3 Oct. 2002.

Programa Cooperativo Centroamericano de Mejoramiento de Cultivos y Animales (PCCMCA) Annual Meeting, La Ceiba, Honduras. 28 April - 2 May 2002.

American Society of Agronomy Meetings, Indianapolis, IN. 10 -14 Nov. 2002.

Seyni Sirifi, IFDC/Soil Management CRSP Soil Fertility Workshop. Lome, Togo. Oct. 2002.

Research Investigator Exchange

Nouri Maman (Niger) completed his Ph.D. degree (May 2003) and Delon Kathol (U.S.) will complete his M.S. degree in the coming year. Nanga Kaye Mady (Chad) started a M.S. degree in May 2003.

Research Information Exchange

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

Purchased chlorophyll meters for research use in El Salvador and Nicaragua. A packet of research articles was sent to help collaborators use the chlorophyll meters effectively in research.

Pearl millet growth and nutrient uptake data was shared with Dr. Gerrit Hogenboom, Univ. of Georgia and SANREM CRSP for modeling research and development of decision aid tools.

Visited INTSORMIL research efforts in El Salvador and Nicaragua in Oct 2002 and April 2003.

Publications and Presentations

Abstracts

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Maman, Nouri, D.J. Lyon, S.C. Mason, T.D. Galusha and R. Higgins. 2003. Pearl millet and grain sorghum yield response to water supply in Nebraska. Agron.J. 95: (In Press).

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Dissertation/Thesis

Maman, Nouri. 2003. Water and Nitrogen Use of Pearl Millet and Grain Sorghum in Nebraska. Ph.D. Dissertation. University of Nebraska, Lincoln, NE.

Book Chapter

Blumenthal, J.M., D.D. Baltensperger, K.G. Cassman, S.C. Mason and A.D. Pavlista. 2001. Importance and effect of nitrogen on crop quality and health, p. 45 - 63. IN R.F. Follett and J.L. Hatfield (eds.). Nitrogen in the environment: Sources, problems and management. Elsevier, Amsterdam, The Netherlands.

Soil and Water Management for Improving Sorghum Production in Eastern Africa

Project UNL 219

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Summary

Farmers working with researchers in Ethiopia have tentatively identified niches and opportunities for tillage alternatives and for tie-ridge and planting implements, and research is continuing in four semi-arid sorghum production areas. In northern Ethiopia, sorghum grain and biomass yields were 142 and 88% more with fertilizer application compared to no fertilizer in six on-farm trials. Research on water and nutrient management was initiated in Uganda in 2003 using participatory approaches. Research on P sorption for diverse soils of Ethiopia and Uganda is showing results of soil properties that are important to P sorption, including the importance of termite activity on sandy soils. Preparations have been made to begin data collection for a sorghum production database and atlas for eastern and southern Africa.

Sorghum yield was not increased with the use of starter fertilizers in eastern Nebraska in 2002 but it was a dry year; this research is continuing with six trials established in 2003. The results of research to validate a nitrogen credit to sorghum following soybean in rotation of 84 kg N ha^{-1} generally support this N credit but the results have not been fully consistent; more trials will be conducted to better understand this N rate by environment interaction in 2004. The potential of occasional tillage as a mean to improving agronomic and environmental aspects of no-till systems has been found to be feasible; additional research on occasional tillage is underway as a Ph.D. dissertation topic. Six graduate students are being partly or fully supported by this INTSORMIL project. Drs. Mamo and Wortmann visited collaborators and research areas in Ethiopia and Uganda and hosted two visiting scientists from Ethiopia.

Objectives, Production and Utilization Constraints

- Conduct nutrient management and water conservation research, such as use of tie-ridging or micro-catchments, in two semi-arid areas in Ethiopia.
- Conduct on-farm trials and/or collaborate in on-going station trials to verify N credit to sorghum following soybeans in rotation after soybeans.
- Conduct research on starter fertilizers for no-till sorghum production in Nebraska.
- Implement research to predict P fixation capacity of soils across Nebraska and Ethiopia and assess effect of tillage systems on organic matter.
- Initiate 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 water and nutrient management research, as well as study of nutrient dynamics in the soil and in the crop.

Research Approach and Project Output

Nutrient and water management research in 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. Trials have been established in four semi-arid sorghum production locations in 2003 with varying elevation ranging 1300 to 1800 m. The locations include Welench'iti, Miesso, Sirinka and Mekelle at Abergele with trials on 3 to 6 farms per site for both April, at some locations, and June planting. In 2002, yield results were obtained at only one location, Abergele, due to drought conditions but farmer assessments were obtained from three locations. Main plot treatments vary according to location but generally include some variation of the following:

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

Tie ridging using modified *maresha* (a test implement) with tie ridges made before planting. Plant in the furrow with a row planter (test implement).

In-furrow row planting with test implement but tie ridge at first weeding with the modified *maresha*.

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

Farmers identified water deficits, low soil fertility, runoff associated with soil crusting and compaction, as well as *Striga*, as major constraints to sorghum production. Water loss to runoff in May and June is of major concern. Tie-ridging using a modified traditional plow (*maresha)* was seen as easy to use but not very good on stony soil. The draft requirements of the ridger were not too great for the oxen, even in May when oxen are often weakest. The oxen-drawn row planter was tested at Miesso and Wolenchiti where the cooperating farmers determined it to be appropriate for their needs as it was easy to use and gave good placement of seed and fertilizer. Farmers thought that tie-ridging and conservation tillage would be appropriate in their communities with conservation tillage preferred for stony or sandy soils and for those with inadequate access to draft power. Farmers emphasized that significant adoption will require farmer training in the use of the implements and the alternative tillage systems. The preliminary results suggest a need for further investigation of the *maresha* tie-ridger for fine texture soils that are not stony; for sandy and stony soils, the traditional *shilishalo* tillage or conservation tillage systems may be more appropriate. At Mekelle-Abergele in 2002, 6 trials were successfully implemented and grain and biomass yields were 142 and 88% more with fertilizer applied as compared to no fertilizer. There was no effect of tillage method, probably due to lack of heavy rainfall events.

P fixation of soils from Ethiopia and Uganda- Phosphorus sorption isotherms were determined for 30 soil samples collected in Ethiopia and Uganda to the 0-15 cm depth in November 2002. In Ethiopia, sampling was along transects from Debre Zeit east to Miesso and north to Mekelle. In Uganda, samples were collected in five districts of central and eastern Uganda. As termites have much influence on soil properties in Uganda, companion soil samples were also collected from and near termite mounds to evaluate effects on P holding capacity. P sorption maximum and P saturation index (PSI) were well correlated (Fig. 1). P sorption maximum increased moving south from entisol of northern Ethiopia to the more developed central and eastern vertic soils (Fig. 1). However, in the Abergelle region, red soil exhibited much lower P holding capacity than black soil located within few meters. Sand and clay contents of Uganda soils affect P sorption capacity. For sandy soils, soil from termite mounds had greater P sorption capacity than nearby soils while the opposite was true for clay loam soils.

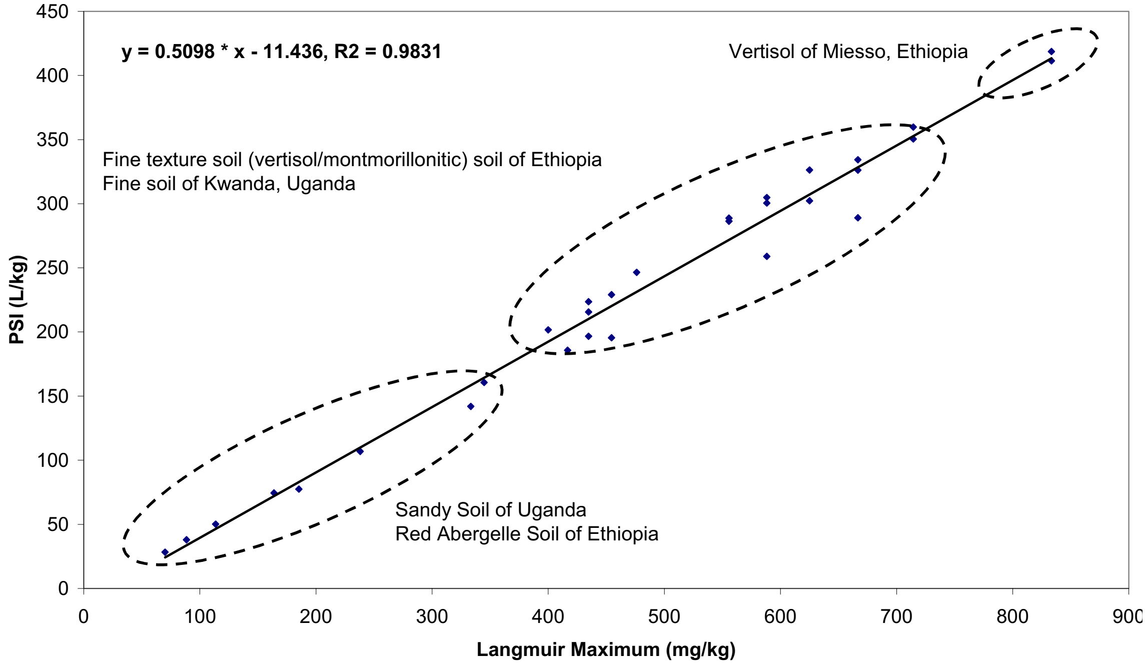

Fig. 1- P Saturation Index (PSI) and Langmuir Sorption Maximum

Table 1. Grain sorghum performance as affected by starter fertilizer treatments in 2002; means of 6 trials conducted under non-irrigated, no-till conditions in eastern Nebraska.

	Plants ha^{-1} 000	Early plant weight g $plant^{-1}$	Yield Mg ha^{-1}
No starter	86.8	5.65	6.20
22-22, 5x5	90.3	5.96	6.38
22-22, over the row	93.3	6.01	6.30
11-11, in-furrow	83.7	5.63	6.21
22-22-0-11, 5x5	91.2	6.14	6.06
22-22-0-11, over the row	90.5	5.54	6.14
11-11-0-6, in-furrow	86.3	6.31	6.08
11-11-0-6, in-furrow with ATS	87.6	5.89	6.17
LSD 0.10	6.02	0.412	0.29

Nutrient and water management research in Uganda. Research was been initiated with farmers in Kumi district in 2003. Farmers, together with research and extension staff, identified priority problems and research topics. On-farm research was conducted during the first season of 2003 but results are not yet available.

Starter fertilizer for no-till sorghum production in Nebraska. In 2002, 6 grain sorghum trials with 4 replications were conducted on farmers' fields across diverse topographic positions/soil types in Gage county of southeastern Nebraska. All sites had a history of continuous no-till and were non-irrigated. Soil pH ranged from 5.3 to 6.1. Soil organic matter was generally more than 3%. Bray-1 P ranged from low to very high. Potassium levels were high at all sites.

Three placement positions were compared: in the seed furrow (in-furrow), over the row, and 5 cm to the side of the row and 5 cm deep (5x5). Liquid starter fertilizer treatments (Table 1) were applied as N+P and N+P+S at the rates of 22 kg ha^{-1} each for N and P, and 11 kg ha^{-1} for S. Half rates were applied with in-furrow application. Ammonium sulfate was the main sulfur source but was compared to ammonium thio-sulfate (ATS) for in-furrow application.

The average density was 88,712 plants ha^{-1} (Table 1). Treatment effects did not have a significant effect but the mean density with in-furrow placement was 85,000 plants ha^{-1} compared to 91,390 for other placements. Early plant weight was greatest with 22-22-0-11 placed 5x5 and with 11-11-0-6 placed in the seed furrow. The average sorghum grain yield was 6.2 Mg ha^{-1} but yield was not affected by starter fertilizer treatment. Results for nutrient uptake are not yet available. Grain yield was not related to early plant growth but plots with more early growth tended to have more heads per acre at harvest time (r = 0.49).

Soybean N credit verified for grain sorghum in Nebraska. The UNL nitrogen recommendation for grain sorghum considers expected yield, soil organic matter, soil nitrate-N, and the effect of a previous legume crop. Recent results from on-station research indicate that the mean N benefit to grain sorghum following soybean is 90 kg N ha^{-1} while current recommendations allow 50 kg N ha^{-1}. This research was undertaken to verify a credit of 84 kg N ha^{-1} or to determine the conditions for when this credit is valid.

On-farm trials of four replications are being conducted in southeast Nebraska where the treatments are: 0 N; and the UNL recommendation giving 0, 50, and 84 kg ha^{-1} N credit for soybean. The results from 3 of 4 trials conducted in 2001 and 2002 give verification to the 84 kg N ha^{-1} credit (Table 2). The results of the Nagel trial indicate that 50 kg N ha^{-1} is a better

Table 2. Grain sorghum yield at various N fertilizer rates to verify a 84 kg (75 lb) N credit to sorghum following soybean in rotation.

	Fisser 2001	Nagel	Gronewald A 2002	Gronewald B	Mean
No N applied	4.39	3.91	4.74	6.59	4.90
84 kg N credit	5.66	4.02	5.09	6.22	5.25
50 kg N credit	5.36	5.32	5.17	6.53	5.60
No N credit	5.68	4.94	5.54	6.39	5.64
Sign.	*	*	0.066	0.71	*
LSD 0.05	1.07	1.07	0.61	0.77	0.57
Estimated N need before credits (lb/A)	112	140	78	95	

estimate of the credit. More information is needed to complete the verification.

Tillage and organic matter in Nebraska. Production of the sorghum-soybean rotation and the corn-soybean rotation in no-till systems is common in eastern Nebraska. Improved soil physical properties and increased soil organic matter (SOM) are commonly observed at the 0-5 cm depth with no-till as compared to tillage with little improvement below 5 cm. However, the increase in SOM generally slows or ceases after a few years of no-till. To increase no-till benefits, we hypothesized that occasional tillage of no-till, e.g. once in 15 years, may increase yield over time, improve surface soil to greater depth, and increase C sequestration. The effects of plow-disk tillage versus no-till, and occasional tillage of no-till, on SOM, particulate organic matter (POM), and wet aggregate stability were determined. Soil samples (0-5 cm) were collected from two long-term tillage trials and from a farmer's field where more than 25 years of continuous no-till was interrupted with a single season of disk tillage in 2001 in randomized strips across the field (the Occasional Tillage Trial). The occasional tillage trial was sampled one year after the tillage event. POM and POM:SOM were less with plow-disk tillage than with no-till (Table 3), but SOM was not significantly affected in the sorghum-soybean trial. These properties were not affected by the one-time tillage in the occasional tillage trial. Wet aggregate stability was less with plow-disk tillage than with no-till but not affected in the occasional tillage trial (Table 4).

The results show that occasional tillage can be conducted in no-till systems without soil degradation. Further research is being conducted on no-till production of sorghum and soybeans to determine if the hypothesized benefits of occasional tillage will be achieved.

Table 3. Effects of tillage on soil organic matter fractions.

	POM	SOM	POM:SOM
	Mg g^{-1}		%
	RMF-corn		
Plow-disk	4.1	36.3	11.4
No-till	14.4	48.0	30.0
LSD 0.05	1.93	3.08	2.62
	RMF-sorghum		
Plow-disk	3.9	34.4	11.4
No-till	8.8	39.5	22.2
LSD 0.05	3.02	5.86	4.59
	Occasional tillage		
Continuous no-till	9.2	33.4	27.6
No-till, disk, no-till	10.2	34.9	24.5
LSD 0.05	1.74	2.25	3.41

Table 4. Tillage effects on wet aggregate stability determined as the percent of aggregates retained following wet sieving.

	Aggregate size fractions, mm				
	2.0 – 8.0	4.0 – 8.0	2.0 – 4.0	1.0 – 2.0	0.50 – 1.0
	RMF-corn				
Plow	47.5	46.9	48.2	49.5	69.0
No-till	61.2	62.1	60.3	67.2	80.5
LSD 0.1	3.76	3.61	4.06	3.48	3.91
	RMF-sorghum				
Plow	43.0	44.2	41.9	45.4	64.8
No-till	50.6	50.8	50.4	55.1	73.4
LSD 0.1	5.66	5.64	6.47	8.81	5.55
	Occasional tillage				
No-till	68.1	71.9	64.4	66.3	83.3
No-till, disk, no-till	65.0	66.3	63.8	68.1	84.0
LSD 0.1	4.38	6.15	4.37	4.94	3.20

Networking Activities

During the INTSORMIL PI conference in November of 2002, we discussed the possibility of the compilation and publication of sorghum production database and atlas for use in regional policy formulation, research, and extension with John Lynam of the Rockfeller Foundation, Seyfu Ketema of ASARECA, and Anthony Obilana of ICRISAT-ECARSAM; collection of data in Ethiopia, Kenya and Uganda is being arranged. Dennis Friesien, CIMMYT-Nairobi and Dr. George Brhane of the Amhara regional development project have expressed interest to collaborate in an extension training program on tillage and water and nutrient management in 2004 and in subsequent extension activities. Dr. Wortmann participated in the First National Sorghum and Millet Research, Extension and Production workshop in Ethiopia, Nov. 12 to14, 2002.

Publications and Presentations

Farmer Assessment of Tillage Systems for Soil and Water Management in Sorghum Producing Areas of Ethiopia. By Worku B., Tewodros M., Zenbaba G., Neway M., Paulos T., and Jibril M., EARO-Nazret Research Center; Gebreyesus B. and Amare B., EARO-Mekelle Research Center; M. Mamo and C. Wortmann, University of Nebraska. Presented at the INTSORMIL PI conference, Addis Ababa, Ethiopia, Nov. 17-23, 2002.

Soil and Water Management for Improving Sorghum Production, by Charles Wortmann and Martha Mamo presented at the INTSORMIL PI conference, Addis Ababa, Ethiopia, Nov. 17-23, 2002.

Soil and Water Management for Improving Sorghum Production, by Charles Wortmann and Martha Mamo presented to the Agronomy and Horticulture Advisory Board, March 27, 2003.