COMPLEMENTARY EFFECTS OF TIED RIDGING AND FERTILIZATION WITH CULTIVATION BY HAND AND DONKEY AND OX TRACTION

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Burkinabe farmers, like most farmers in the West Africa Semi-Arid Tropics (WASAT) are largely subsistence farmers (FSU/SAFGRAD, 1982). In a country where rainfall is limited and unpredictable (Matlon, 1983), farmers are risk averse and work on a limited and fragile soil resource base (Charreau, 1977 and Pichot et al., 1981). Amelioration of the soil base is imperative if it is to support more intensive crop production. Risk is an obstacle to more intensive crop production, particularly when cash inputs are required. Technologies should maximize the use of non-purchased inputs, still using minimal applications of purchased inputs. Technologies should be designed to minimize risk associated with the use of cash inputs. Promising technologies include :

(1) construction of tied ridges resulting in catchment basins to reduce rainfall runoff and thereby increase the amount of water available to the plants, and
(2) fertilization.

Results from experiment station trials have shown that tied ridges can result in significant cereal yield increases compared to flat cultivation or simple ridging (Rodriguez, 1982, 1983; ICRISAT, 1981; IRAT, 1982), but the amount of crop yield response has been variable. Cereal crop yield response in farmer-managed trials has generally been less (FSU/SAFGRAD, 1982; Lang et al., 1983; Rodriguez, 1982) than in experiment station trials.

The variable response from tied ridging is undoubtedly due to several interacting factors, including level of soil fertility, amount and frequency of rainfall, moisture stress at seeding, whether tied ridges are constructed at or prior to seeding, position of crop area along the toposequence, soil type, quality of the tied ridges, and crop growth stage when tied ridges are constructed. Crop yield response to tied ridging is generally greater when soil fertility is less limiting (Rodriguez, 1982 and 1983; FSU/SAFGRAD, 1983 and 1984).

Significant cereal yield responses to fertilization with NPK have been demonstrated (synthesis by Matlon, 1983 of trials by IRAT in Burkina Faso during 1978 to 1982) with financial rates of return of 450, 330 and 37 percent for maize, sorghum and millet, respectively. Farmer-managed trials have shown fertilization to be highly risky in semi-arid conditions. Fertilization of sorghum with 100 kg/ha of 14-23-15 in the 900 mm rainfall zone in Burkina Faso resulted in a 2:1 benefit: cost ratio. Millet fertilized with 100 kg/ha of 14-23-15 in the 500 mm rainfall zone resulted in negative returns (ICRISAT, 1982). In the 900 and 800 mm zones, the proportion of fields where incremental yields did not cover subsidized fertilizer costs were 44 and 70 percent respectively. (ICRISAT, 1982 by Matlon, 1983). In farmer-managed trials by FSU/SAFGRAD, the percentage of farmers who would have lost cash from fertilization

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of sorghum with 100 kg/ha of 14-23-15 plus 50 kg/ha urea ranged from 17% to 58%. The percentage of farmers who would have lost cash by fertilization of millet with 100 kg/ha volta phosphate plus 50 kg/ha urea ranged from 80% to 86% (Lang et al., 1983).

The potential benefits of animal traction include expansion of area cultivated, reduction of labor constraints, and increased yields. The relevance of animal traction to this study is the deeper cultivation of the soil during weeding which enables farmers to construct more effecive tied ridges than with manual cultivation.

The objective of this study is to determine economic returns from investments in tied ridging and minimal fertilization of sorghum, maize and millet under farmer-managed conditions. Data presented here, from trials in 1984, are generally supportive of, but more extensive and conclusive than, data from previous years (FSU/SAFGRAD, 1982; Lang et al, 1983).

MATERIALS AND METHODS

Agronomic and socio-economic research was conducted in five villages (Nedogo, Bangasse, Poedogo, Diapangou and Dissankuy) which represent a wide range of agroclimatic zones and agricultural productivity. In each village a census was taken to identify all households (Lang et al., 1983). From this census a random sample of 30 households was selected. This sample was used as the base for socio-economic surveys which were designed to identify production constraints and to understand the farmers' decision-making environment. A questionnaire was also conducted to find out the extent of adoption of certain technologies. Farmers were asked to comment on the benefits and problems with the new technologies.

Three experiments were conducted on fields of up to 25 randomly chosen farmers in each of one to five villages. The number of treatments for each experiment was five or less. Each treatment was randomly assigned to a parcel of the farmer's field. Parcel size ranged from 0.05 to 0.12 ha, depending upon the size of the farmer's field. The one parcel of each treatment in each farmer's field was considered as an observation. The farmers managed and carried out the experiments and were responsible for all labor inputs. Prior to seeding, FSU field staff stationed in each village delineated each parcel with colored stakes and measured the area of all parcels. FSU field staff frequently visited the farmers to ensure that seeding, application of fertilizer, construction of tied ridges and other tasks were effected correctly and on time. Labour inputs by the farm families were recorded each week by FSU staff on a farmer-recall basis. Prior to harvest, FSU staff evaluated all parcels for general conditons of the crop. Farmers harvested all parcels. FSU staff weighed the harvest from all parcels.

The economic analysis required labor data, prices of grains and fertilizers, and agronomic data. The labor data requirements were the number of hours of labor it took to construct tied ridges and apply fertilizer. For tied ridges, the values of 100, 75 and 75 hours of labor per hectare were used for manual labor, donkey traction, and ox traction, respectively. Because tied ridges are constructed in combi-

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nation with a weeding operation, these figures express the additional time necessary to tie the ridges above that required for the weeding operation. Fertilizer application required 40, 20 or 75 additional hours of labor per hectare when applied, respectively, in the seed rows, or in pockets at 10 to 15 cm from the seed pockets. The labor hour figures are all expressed on a man-hour equivalent basis weighted as follows; one male hour ($\geq$ 15 years) = 1, one female hour ($\geq$ 15 years) = 0.75 and one child hour ($<$ 15 years) = 0.5. The labor data, which was gathered on a farmer recall basis, showed a large variation and with the help of the field staff, the data was carefully screened to arrive at the figures. A 40 CFA/hr opportunity cost for farmers' labor is used in comparing the economic return/hr of the additional labor required to construct tied ridges and/or apply fertilizer.[1] This figure represents a best estimate of the opportunity cost based on field staff observations. Grain prices are the official OFNACER prices in the fall of 1984. The prices are 92 CFA/kg for sorghum, millet and maize. The fertilizer prices are the the official prices (subsidized) in the spring of 1984. The prices are 78 CFA kg for 14-23-15, 88 CFA/kg for urea and 25 CFA/kg for volta phosphate.

Total rainfall during the 1984 growing season was considerably below long-term seasonal average rainfall at all villages. Total rainfall (mm) was 514, 452, 633, 675 and 458 at respectivelly Bangasse, Nedogo, Poedogo, Dissankuy and Diapangou. At Bangasse the rains began early in the season and continued regularly until 15 August. Absence of rainfall from mid-September caused severe drought stress in most cereal fields during flowering and grain fill. At Nedogo rainfall was limited, but occurred regularly and was adequate for fair crop growth. At Poedogo, lack of rainfall delayed seeding of most cereal fields until early July. Beginning mid-July, rainfall was excellent and continued until mi-October. At Dissankuy, lack of rainfall delayed seeding. Throughout the season several large but infrequent rains occurred resulting in several periods of drought stress. At Diapangou, rainfall was limited and infrequent until early July. Rains were small but frequent during September and October.

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[1] Most of the agricultural labor is provided by family members throughout the agricultural season. Although some farmers are able to hire labor in peak periods because of economic or social status, little labor is available for hire at these times. The 40 CFA/hr, opportunity cost is he average of the wagd rates paid for hired labor during the peak labor periods of seeding, first weeding and second weeding. Imperfections in the labor market account for the fact that the wage rates do not substantially change from period to period. However, the marginal product of labor can be four to five times the average wage rate in critical labor shortage periods (Norman et al., 1981; Roth and Sanders, 1984).

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Experiment I. The experiment was conducted at Nedogo with manual traction and donkey traction, at Bangasse with manual traction, at Dissankuy with ox traction and at Diapangou with manual, donkey and ox traction. The four treatments were the following: traditional management practices including flat cultivation and no fertilization, the control (C); construction of tied ridges (TR) one month after seeding and no fertilization; flat cultivation and 100 kg/ha of cotton fertilizer, 14-23-15, applied in a band at 10-15 cm from the rows of sorghum two weeks after seeding plus 50 kg/ha of urea, applied in pockets at 10-15 cm from the seed pockets one month after seeding (F); and construction of tied ridges as described above, plus fertilization as described above. Locally grown varieties of sorghum were utilized.

The experiment was conducted at Dissankuy for the first time in 1984. At Nedogo, Bangasse and Diapangou the experiment was conducted in 1983, and in 1984; treatments were assigned to the same parcels as in 1983. At Bangasse and Dissankuy, the experimental design was a randomized complete block. Farmer's fields were replications. At Nedogo and Diapangou, the experimental design was a split-plot with whole-plots (types of traction) arranged in a completely randomized design. Treatments were the subplots.

Experiment II. The experiment was conducted at Nedogo with donkey traction, Bangasse and Poedogo with manual traction, Dissankuy with ox traction. Local varieties of maize were utilized. The two treatments were the following: traditional management practices including flat cultivation, the control (C) and construction of tied ridges (TR) one month after seeding. It was planned that half of the farmers at Poedogo and Dissankuy (villages at which mulch was most available) were to apply mulch at 5 t/ha to one of the two parcels after construction of tied ridges. It was reasoned that farmers would have access to sufficient mulch for one-half of their compound maize field which is usually very small in area. However, only four farmers at Poedogo and two farmers at Dissankuy had access to sufficient mulch. We abandoned the application of mulch, although these six farmers did apply the mulch. Compound fields, on which maize is usually grown, are relatively well fertilized with manures and organic wastes, and rainfall is usually the most limiting constraint.

The experiment was conducted at Poedogo and Dissankuy for the first time in 1984. At Nedogo, Bangasse and Diapangou the experiment was conducted in 1983, and in 1984. In 1984, treatments were assigned to the same parcels as they were in 1983 to capitalize on residual soil water which might be present as a result of tied ridges in 1983. At Nedogo, Bangasse, Poedogo and Dissankuy the experimental design was a randomized complete block. Farmers' fields were replications. At Diapangou, the experimental design was a plit-plot with whole units (types of traction) arranged in a completely randomized design and treatments were the subunits. The statistical significance of differences between maize yield means of the two treatments (flat cultivation and tied ridges) was determined by the t-test on pairs of observations. A pair of observations, the yield for maize with flat cultivation and the yield for maize with tied ridges, was obtained from each farmer's field.

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Experiment III. The experiment was conducted for the third year in 1984 at Nedogo and Bangasse with manual traction only. Local varieties of millet were utilized. The five treatments were the following: traditional management practices including flat cultivation (without tied ridges) and no fertilization, the control (C); construction of tied ridges (TR) one month after seeding; F, consisting of 100 kg/ha of volta phosphate (VP1) applied in the seed pocket plus 50 kg/ha urea applied in pockets at 10-15 cm from the seed pockets two weeks after seeding, and construction of tied ridges one month after seeding; 2 F, consisting of 200 kg/ha of VP1 and 50 kg/ha urea applied together in a pocket at 10-15 cm from seed pockets two weeks after seeding; and F, consisting of 100 kg/ha VP1 plus 50 kg/ha urea, but without tied ridges.

In 1984, treatments were assigned to the same parcels as in 1982 and 1983 to capitalize on the availability of phosphorus from VP1 applied in previous years. At Nedogo and Bangasse, the experimental design was a randomized complete block. Farmers' fields were replications.

Adoption of technologies. A survey was conducted in November, 1984 by interviewing the FSU farmer cooperators of the farmer-managed trials. The farmers within the farmer-managed trial group also comprise the farmers that FSU collects socio-economic data from. The socio-economic data made it possible to analyze some of the key variables that may distinguish adoptors from non-adoptors.

RESULTS AND DISCUSSION

Experiment I. The relative responses of sorghum to the four treatments was consistent across the four villages: Nedogo, Bangasse, Dissankuy and Diapangou (Table 1). Treatments consisting of tied ridges to reduce surface runoff of rainfall, or fertilization to ameliorate the low soil fertility resulted in increased levels of sorghum yield. However, the greatest yield response was consistently achieved with the combination of tied ridges and fertilization.

Yields of sorghum were generally higher with animal traction than with manual traction. However, at Nedogo, the difference was significant only for the combination of tied ridges and fertilization. At Diapangou, sorghum yields with ox traction were not superior to those with donkey traction. It is possible that the deeper cultivation during weeding with ox traction, compared to donkey traction, accentuated the severe drought conditions in 1984, especially in sandy soils with low organic matter.

The economic analysis shows that for the mean yield increases at all locations, the return/hr for labor inputs to construct tied ridges and/or to apply fertilizer is above the 40 CFA/hr opportunity cost of labor. The combination of tied ridging and fertilization resulted in the largest net returns at all locations. Net returns were larger for fertilization alone than for tied ridging alone at Bangassé and for the three types of traction at Diapangou. Also, the return per hour of additional labor for the combination of tied ridging and fertilization were largest at Bangassé and for the two types of animal traction at Diapangou. With respect to risk, tied ridging alone carries no risk of losing cash. However, the fertilization alone treatment is moderately risky and some farmers at each

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Table 1. Economic analysis of farmer managed trials of sorghum with fertilizer and tied ridges, 1984.

	Treatments 1/				4/	4/	Number of
	C	TR	F	TR,F	S.E	CV	Farmers
Nedogo, Manual Traction							
Grain Yield, kg/ha	157	416	431	652	75.1	43	11
Yield Gain Above Control, kg/ha	-	259	274	495			
Gain in Net Revenue, CFA 2/	-	23828	13275	33607			
Return/hr. of Additional Labor, CFA 3/	-	238	140	172			
% Farmers Who Would Have Lost Cash	-	0	27	9			
Nedogo, Donkey Traction							
Grain Yield, kg/ha	173	425	355	773	63.4	44	18
Yield Gain Above Control, kg/ha	-	252	182	600			
Gain in Net Revenue, CFA	-	23184	4811	43267			
Return/hr. of Additional Labor, CFA	-	309	51	255			
% Farmers Who Would Have Lost Cash	-	0	50	0			
Bangasse, Manual Traction							
Grain Yield, kg/ha	293	456	616	944	145.0	62	12
Yield Gain Above Control, kg/ha	-	163	323	651			
Gain in Net Revenue, CFA	-	14996	17783	47959			
Return/hr. of Additional Labor, CFA	-	150	187	246			
% Farmers Who Would Have Lost Cash	-	0	8	17			
Dissankuy, Ox Traction							
Grain Yield, kg/ha	447	588	681	855	35.1	19	25
Yield Gain Above Control, kg/ha	-	141	234	408			
Gain in Net Revenue, CFA	-	12972	9595	25603			
Return/hr. of Additional Labor, CFA	-	173	101	151			
% Farmers Who Would Have Lost Cash	-	0	28	0			
Diapangou, Manual Traction							
Grain Yield, kg/ha	335	571	729	1006	48.4	23	19
Yield Gain Above Control, kg/ha	-	236	394	671			
Gain in Net Revenue, CFA	-	21712	24315	49799			
Return/hr. of Additional Labor, CFA	-	217	256	255			
% Farmers Who Would Have Lost Cash	-	0	26	0			
Diapangou, Donkey Traction							
Grain Yield, kg/ha	498	688	849	1133	45.6	18	19
Yield Gain Above Control, kg/ha	-	190	351	635			
Gain in Net Revenue, CFA	-	17480	20359	46487			
Return/hr. of Additional Labor, CFA	-	233	214	273			
% Farmers Who Would Have Lost Cash	-	0	21	0			
Diapangou, Ox Traction							
Grain Yield, kg/ha	466	704	839	1177	46.8	18	19
Yield Gain Above Control, kg/ha	-	238	373	711			
Gain in Net Revenue, CFA	-	21896	22383	53479			
Return/hr. of Additional Labor, CFA	-	292	236	315			
% Farmers Who Would Have Lost Cash	-	0	5	0			

1/ C = control (no tied ridges or fertilizer); TR = tied ridges constructed one month after seeding; F = 100 kg/ha 14-23-15 two weeks after seeding plus 50 kg/ha urea one month after seeding.

2/ Net revenue = yield gain x grain price (92 CFA/kg) minus fertilizer cost; (78 CFA/kg for 14-23-15, and 66 CFA/kg for urea), Includes interest charge for six months at rate of 15%.

3/ Net revenue/additional labor of tied ridging and fertilizer application. Manual, Donkey, and Ox traction require 100, 75, and 75 hours of additional labor/ha for tied ridging respectively. Fertilizer application requires 95 additional hours/ha.

4/ S.E. = the standard error of the difference between two treatment means. CV% = coeficient of variation.

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location would have lost cash. The use of tied ridging in combination with fertilization, substantially reduces the farmers' risk of losing cash as opposed to the fertilization alone treatment. When tied ridges and fertilizer are combined, only 9% of the farmers at Nedogo with manual traction and 17% of the farmers at Bangassé with manual traction would have lost cash. Only at these two locations is the tied ridging-fertilization combination a greater risk than tied ridges alone. However, the low-risk tied ridging options results in substantially reduced net returns when compared with the tied ridging-fertilization combination.

Experiment II. Because of drought conditions which were particularly damaging to maize in 1984, several farmers in each village failed to construct the tied ridges and these fields were abandoned. This resulted in a limited number of observations for treatments. Although the number of observations was less than desired, the results show that at all villages, representing a wide range of yield levels, maize with tied ridges produced greater yields than maize without tied ridges (Table 2). At Diapangou the experiment was conducted with manual traction and with ox traction. With both types of traction, yields of maize with tied ridges were significantly greater than yields of maize without tied ridges. Maize with ox traction produced significantly greater yields than maize with manual traction.

The economic analysis shows that in all trials, the mean yield increase from constructing tied ridges compared to that of flat cultivation results in labor returns/hr which are much greater than the 40 CFA/hr opportunity cost is moderately high at the Nedogo, Poedogo and Diapangou (manual traction) locations. Assuming farm labor can earn 40 CFA/hr in other employment opportunities, some farmers would have been better off doing so at all locations with the exception of ox traction at Diapangou. The results, however, do emphasize the value of water conservation by the construction of tied ridges on the fertile compound fields where maize is grown.

Experiment III. Grain yields of millet for the treatments (tied ridges in combination with fertilization or fertilization alone) tended to be greater than yields of millet without tied ridges or fertilization at Nedogo and Bangasse (Table 3). However, yield differences from that of the control were significant only for the combination of tied ridges and fertilization at Bangasse and for treatments consisting of tied ridges and/or fertilization at Nedogo. Responses from treatments involving fertilization were generally greater in 1984 than in 1983 (Lang, et al., 1983) or 1982 (FSU/SAFGRAD, 1982).

Tied ridges without fertilizer resulted in a significant yield increase compared to the control at Nedogo. This treatment requires no cash inputs, but this practice cannot solve the problem of soil fertility improvement over years. Tied ridges in combination with fertilization resulted in the greatest yield of millet in 1984, which is consistent with our results in 1982 and 1983.

The mean yield increases at Nedogo and Bangasse for the two treatments which involve tied ridging (TR) and tied ridging plus fertilization (TR, F) are adequate to cover the opportunity cost of labor. When ferti-

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Table 2. Economic analysis of farmer managed trials of maize with tied ridges, 1984.

	Treatments 1/			Number
	C	TR	6/ CV	of Farmers
	Nedogo, Donkey Traction			
Grain Yield, kg/ha	869	1305**** 5/	26	19
Yield Gain Above Control, kg/ha	-	436		
Gain in Net Revenue, CFA 2/	-	40112		
Return/hr. of Additional Labor, CFA 3/	-	535		
% Farmers Not Covering Labor Opp. Cost 4/		21		
	Bangasse, Manual Traction			
Grain Yield, kg/ha	341	466****	62	12
Yield Gain Above Control, kg/ha	-	125		
Gain in Net Revenue, CFA	-	11500		
Return/hr. of Additional Labor, CFA	-	115		
% Farmers Not Covering Labor Opp. Cost		8		
	Poedogo Manual Traction			
Grain Yield, kg/ha	1339	1953*	43	8
Yield Gain Above Control, kg/ha	-	614		
Gain in Net Revenue, CFA	-	56488		
Return/hr. of Additional Labor, CFA	-	565		
% Farmers Not Covering Labor Opp. Cost		25		
	Dissankuy, Ox Traction			
Grain Yield, kg/ha	564	725****	16	16
Yield Gain Above Control, kg/ha	-	161		
Gain in Net Revenue, CFA	-	14812		
Return/hr. of Additional Labor, CFA	-	197		
% Farmers Not Covering Labor Opp. Cost		6		
	Diapangou, Manual Traction			
Grain Yield,kg/ha	445	724**	69	7
Yield Gain Above Control, kg/ha	-	279		
Gain in Net Revenue, CFA	-	25668		
Return/hr. of Additional Labor, CFA	-	257		
% Farmers Not Covering Labor Opp. Cost		29		
	Diapangou, Animal Traction			
Grain Yield, kg/ha	976	1700***	46	7
Yield Gain Above Control, kg/ha	-	724		
Gain in Net Revenue, CFA	-	66608		
Return/hr. of Additional Labor, CFA	-	888		
% Farmers Not Covering Labor Opp. Cost		0		

1/ C = control (no tied ridges or fertilizer); TR = tied ridges constructed one month after seeding.
2/ Net revenue = yield gain x grain price (92 CFA/kg)
3/ Net revenue/additional labor of tied ridging. Manual, Donkey, and Ox traction require 100, 75, and 75 hours of additional labor/ha for tied ridging respectively.
4/ A 40 CFA/hr. opportunity cost of labor is used.
5/ *,**,***, and **** indicate a level of significance of 0.2, 0.05, 0.02, and 0.01 respectively for differences between treatments C and TR as determined by the T-Test for paired observations.
6/ CV% = coeficient of variation

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Table 3. Economic analysis of farmer managed trials of millet with volta phosphate and tied ridges, 1984.

	Treatments 1/							Number
	C	TR	TR,F	2F	F	S.E. 4/	CV 4/	of Farmers
Nedogo, Manual Traction								
Grain Yield, kg/ha	107	238	349	228	195	28.0	32	11
Yield Gain Above Control, kg/ha	-	131	242	121	88			
Gain in Net Revenue, CFA 2/	-	12052	16029	2209	1861			
Return/hr. of Additional Labor, CFA 3/	-	121	75	29	16			
% Farmers Who Would Have Lost Cash	-	0	0	55	55			
Bangasse, Manual Traction								
Grain Yield, kg/ha	220	283	469	251	273	40.3	39	17
Yield Gain Above Control, kg/ha	-	63	249	31	53			
Gain in Net Revenue, CFA	-	5796	16673	-6071	-1360			
Return/hr. of Additional Labor, CFA	-	58	78	-	-			
% Farmers Who Would Have Lost Cash	-	0	6	59	59			

1/ C = control (no tied ridges or fertilizer); TR = tied ridges constructed one month after seeding; F = 100 kg/ha volta phosphate applied in the seed pocket and 50 kg/ha urea applied in pockets 10-15cm from seed pockets two weeks after seeding ; 2F = 200 kg/ha volta phosphate and 50 kg/ha urea applied together in a pocket 10-15cm from seed pocket two weeks after seeding.

2/ Net revenue = yield gain x grain price (92 CFA/kg) minus fertilizer cost; (25 CFA/kg for Volta Phosphate and 66 CFA/kg for urea), Includes interest charge for six months at rate of 15%.

3/ Net revenue/additional labor of tied ridging and fertilizer application. Manual traction requires 100 hours of additional labor/ha for tied ridging. Fertilizer application requires 115 additional hours/ha for F and 75 additional hours/ha for 2F.

4/ S.E. = the standard error of the difference between two treatment means. CV% = coeficient of variation.

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lizer is used alone at both locations, mean yield increases are not sufficient to cover the opportunity cost of labor. At both locations, the combination of tied ridging and fertilization provided the largest net returns, emphasizing the gains which can be made by combining soil fertility and water conservation. It is important to note that millet response to improved soil-water management would likely be greater in the presence of a more soluble source of phosphorus.

In the economic analysis, net returns are calculated without considering the carry-over effect of fertilizer from one year to the next. The amount of fertilizer carry-over varies with rainfall and the type of fertilizer. There is considerably more carry-over of volta phosphate than either 14-23-15 or urea.

Assuming that 25 percent of the value of 14-23-15 and urea and 75 percent of the value of volta phosphate is carried over each year with an opportunity cost of 15 percent, the economic relationships among the treatment, made in the paper still hold.

Adoption of technologies. The FSU program is research-oriented and not specifically designed for an extension role. Although FSU research involves direct interaction and feedback from the farmer cooperators, any adoption by farmers of the technologies that FSU works with is not sollicited by FSU but is a welcome externality of the program. The FSU farmer-managed and researcher-managed trials, however, do provide a demonstration effect and add to the programs provided by the local extension services. When asked who introduced them to tied ridges, 95 percent of the farmers said FSU. Across all villages with the exception of Dissankuy, a similar question of fertilizer brought the response that 50 percent of the farmers were introduced to fertilizer by FSU and 50 percent by the local extension service (Ohm, et al., 1984).

Data are presented on a number of farmers basis (Table 4) and on a hectarage basis (Table 5). A demonstration effect was evident in that some farmers adopted the tied ridging, fertilization and new variety technologies in the FSU villages. A positive relationship between adoption and the number of years FSU worked in the villages was evident for tied ridges. The adoption rates may, however, have been hampered by the poor 1983 and 1984 agricultural seasons. The primary reason for not adopting tied ridging more extensively was lack of sufficient labor. The farmers said that financial conditions of not having the cash or not being able to obtain credit was the primary reason for not utilizing more fertilizer. Farmers were generally hesitant about trying new varieties until they could give them a good appraisal.

In summarizing the characteristics of adoptors and non-adoptors, the main characteristic of tied ridge adoptors is that they have larger tnan average size land holdings. Other characteristics are a larger than average cash crop area and a higher management level. All three characteristics showed up most noticeably in Nedogo and Bangasse. The main characteristic of new variety adoptors was farm size and the other characteristics were cash crop area and management level all exhibiting a positive relationship. The Poedogo fertilizer case indicated that younger farmers used fertilizer. Other characteristics included farm size and management level.

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Table 4. Percent of farmers adopting tied ridges (TR), fertilizer and new varieties by village, 1984.

Village	Years[1]	Number of Farmers	Percent of Farmers Adopting		
			TR	Fertilizer	Varieties
Nedogo	5	69	25	10	10
Bangasse	3	53	23	0	0
Poedogo	2	27	4	33	41
Dissankuy	2	60	2	97[2]	0
Diapangou	3	61	25	8	8

[1] Number of years FSU in villages; 1984 was the first year for farmer-managed trials at Poedogo and Dissankuy.

[2] The figures relate only to land sown to cotton. Small amounts of fertilizers are used on cereals.

Table 5. Average hectares of technology adoption, 1984.

Technology	Village				
	Nedogo	Bangasse	Poedogo	Dissankuy	Diapangou
	ha				
Tied Ridges	.32	.03	.11	.03	.18
Fertilizer	.46	0	3	3	.34
Varieties	.33	0	.12	0	.04

The characteristic that consistently showed the strongest relationship to adoption in all cases was farm size. Farmers controlling larger land areas are associated with adopting the technologies. Perrin and Winkel mann (1976) found similar results with respect to farm size for new varieties in countries where variety introductions were recent. Underlying the size effect are the factors of economies of size in the transaction costs of evaluating and acquiring new technologies, differences in prices for inputs and products, and difference in land productivity (Perrin and Winkelmann, 1976). Given that farmers with large sized farms may be the first adoptors of technology as is suggested by this preliminary analysis, questions concerning future income distribution should be pursued.

SUMMARY

Three farmer-managed experiments were conducted on fields of up to 25 randomly chosen farmers in each of one to five villages with manual cultivation and/or cultivation with donkey and/or ox traction. Treatments for the experiment with sorghum were a control, construction of tied ridges one month after seeding, fertilization with 100 kg/ha 14-23-15 plus 50 kg/ha urea and the combination of tied ridging and fertilization. Treatments for the experiment with maize grown on compound fields were a control and tied ridging. The third experiment, with millet, involved five

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treatments: a control tied ridging, fertilization with 100 kg/ha volta phosphate (VP1) plus 50 kg/ha urea, 200 kg/ha VP1 plus 50 kg/ha urea and the combination of tied ridging and 100 kg/ha VP1 plus 50 kg/ha urea. The economic analysis accounted for labor inputs, prices of grains and fertilizers and agronomic data.

Construction of tied ridges can result in significant increases of cereal crop grain yields throughout the Central Plateau even on areas with very gentle slopes. This is because the water infiltration rates are low for most of the soils, partially due to low organic matter, and with flat cultivation, much of the limited rainfall is lost due to surface runoff. Although tied ridges constructed prior to planting can result in greater yields than tied ridges constructed later in the season, it is usually impractical to construct them prior to first or second weeding. Because seeding is done manually, availability of labor is a serious constraint and because seeding must be effected as soon as possible after rains which may be infrequent during May and June, there is no time or available labor to construct tied ridges or till the soil prior to seeding.

An alternative is to construct tied ridges as soon as possible after plant emergence. For most farmers this is during second weeding when plants are tall enough and when labor is slightly more available than earlier in the season. With presntly available equipment (daba or weeding equipment including the butteur and houe-manga) construction of tied ridges even when weeding with animal traction involves substantial manual labor. Because of the large amount of labor required, tied ridges may not be generally accepted although several of the FSU/SAFGRAD cooperator-farmers do practice tied ridging on areas other than those of FSU farmer-managed trials.

A promising alternative is the use of a mechanical tied ridger which attaches to a butteur to construct tied ridges during weeding and which would require no additional manual labor. A low-cost, easy-to-operate mechanical tied ridger has been developed and on-farm research must now be conducted to determine its effectiveness and farmer reactions.

Fertilization with minimal amounts of cotton fertilizer (100 kg/ha) plus 50 kg/ha urea can result in significant yield increases. However, sorghum yield response to fertilization without tied ridging is variable and involves the risk of losing the cash cost of the fertilizer. In addition, the problems of fertilizer purchases and availability of fertilizers must be dealt with. Experimentation to determine benefits from possible accumulation of nutrients in successive years of fertilization with minimal amounts of fertilizers should be continued. In a very dry season it is probable that not all of the applied nutrients even at minimal rates of application, will be removed by crop growth. The inconsistent responses to fertilization with VP1, UV5 and urea compared to the more consistent responses from cotton fertilizer (Ohm et al., 1984) suggests that more research is needed to characterize soils for concentrations of a broad range of nutrient elements essential for crop growth.

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