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INTRODUCTION

With FSU and IITA/SAFGRAD collaboration, a prototype mechanical ridge tier was tested in the field as part of Burkina's (IBRAZ) 1985 national farming systems field trial program. FSU oversaw the field trials and socio-economic data collection with the aid of the national farming systems field staff. The objective of this paper is to report the findings from the field trials and socio-economic campaign.

BACKGROUND INFORMATION

In Burkina Faso and in the sahel and sudanian regions of Africa in general, low soil fertility, lack of soil water retention and availability, and labor shortages are major constraints to increased yield and production. FSU has focused a major part of its efforts on these problems and in particular have worked with soil fertility increasing methods (fertilizers, manures, and mulch) and with the water retention technique of tied ridging.

Tied ridges are small depressions made between the crop rows either by hand tillage or with a combination of animal traction and hand tillage. If done by hand, depressions 32 cm long x 24 cm wide x 16 cm deep are made between the rows spaced 1 1/2 meters apart. If done with animal traction, the cultivator (Houe Manga) is equipped with a middle sweep to create a furrow which is then followed by hand tillage to make a 16 cm high ridge perpendicular to the furrow every one to two meters. The depressions catch and hold water after a rain and increase soil water infiltration and retention. Both methods are very labor intensive.

Tied ridging is not a new technique and previous research has been undertaken on the subject (Dagg and Macartney, 1968). More recently, there has been work on tied ridging in Burkina Faso indicating that tied ridging can result in significant yield increases (ICRISAT; IITA/SAFGRAD; Rodriguez, 1982; IRAT; Dugue, 1985; Nicou and Charteau, 1985). FSU on-farm trials (both researcher-managed and farmer-managed) indicate that either the use of commercial fertilizers or the water retention technique of tied ridging can increase yields of maize, sorghum and millet but have their greatest effect on yields when used in combination (Lang et al, 1984, and Ohm et al., 1985a and 1985b).

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[1]The Purdue University Farming Systems Unit (FSU) is part of the Semi-Arid Food Grain Research and Development project (SAFGRAD) and collaborates with the national farming systems program within the Institut Burkinabe de Recherches Agronomiques et Zootechniques (IBRAZ).

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FSU socio-economic data indicated that the use of tied ridging and fertilization together was profitable and gave a higher economic return than when the technologies were used separately. Although tied ridges can be profitable alone, fertilizer application alone is very risky and the incidence of farmers losing their cash outlay is very high (Lang et al., 1984 and Ohm et al., 1985a and 1985b). Socio-economic data also pointed out that there is a labor constraint during the planting to second weeding period within the agricultural season - particularly at the planting and first weeding stages of the major subsistence crops. To be most beneficial, the labor intensive tied ridges need to be constructed within the period from planting to second weeding - the period of high labor demand. Farmer interviews indicated that farmers see the benefits from tied ridging but say they do not have the labor to construct them on other than small areas of their land. A survey of the adoption of technology by farmers in FSU villages in the fall of 1984 indicated that the number of farmers constructing tied ridges and the hectarage of tied ridging construction outside of trial plots was small (Ohm et al., 1985a and 1985b).

The information on the labor shortage was communicated to other researchers within SAFGRAD, and in the Fall of 1983 a Peace Corps Volunteer with the IITA/SAFGRAD maize agronomy program (Jeff Wright) started work on a prototype mechanical device (Fig. 1.) to tie the ridges (Wright and Rodriguez, 1985). The mechanical device is attached to an animal drawn cultivator with one large middle sweep. The ridging and tying of the ridge can be done simultaneously in one pass through each crop row or the operation can be done in two passes. With two passes the rows are first ridged by the cultivator in the normal way and then in a second pass the ridges are tied by the mechanical ridge tier (MRT) which is attached to the cultivator. In the second pass the cultivator is equipped with a smaller middle sweep. The device is essentially a paddle wheel (45 cm in diameter) with four paddles, one scraping the ground, building up earth until it is tripped by the operator every 1 1/2 to 2 meters to create the tie in the ridge. Two sizes of the MRT were made; one for donkey traction as presented in Fig 1 and one for ox traction which is a similar model but slightly larger.

OBJECTIVES AND METHODOLOGY

The objectives of the mechanical ridge tier field campaign were threefold; 1) to obtain and compare yield and other agronomic data of the MRT to flat cultivation and to animal traction ridges tied by hand, 2) to assess the economic profitability and labor demands of the MRT and 3) to obtain technical data about the MRT and question farmers about the operation of the MRT.

Three village sites were selected for the field trials and socio-economic data collection (Fig. 2) and are as follows: Nedogo, 30 km north-west of Ouagadougou; Poedogo, 130 km south of Ouagadougou; and Diapangou, 15 km west of Fada. Eight farmers with donkey and 7 farmers with ox traction were selected in Nedogo, 15 farmers with donkey traction were selected in Poedogo and 15 farmers with donkey and 15 farmers with ox traction were selected in Diapangou. Most of the farmers selected would be classified as good to very good and experienced with animal traction.

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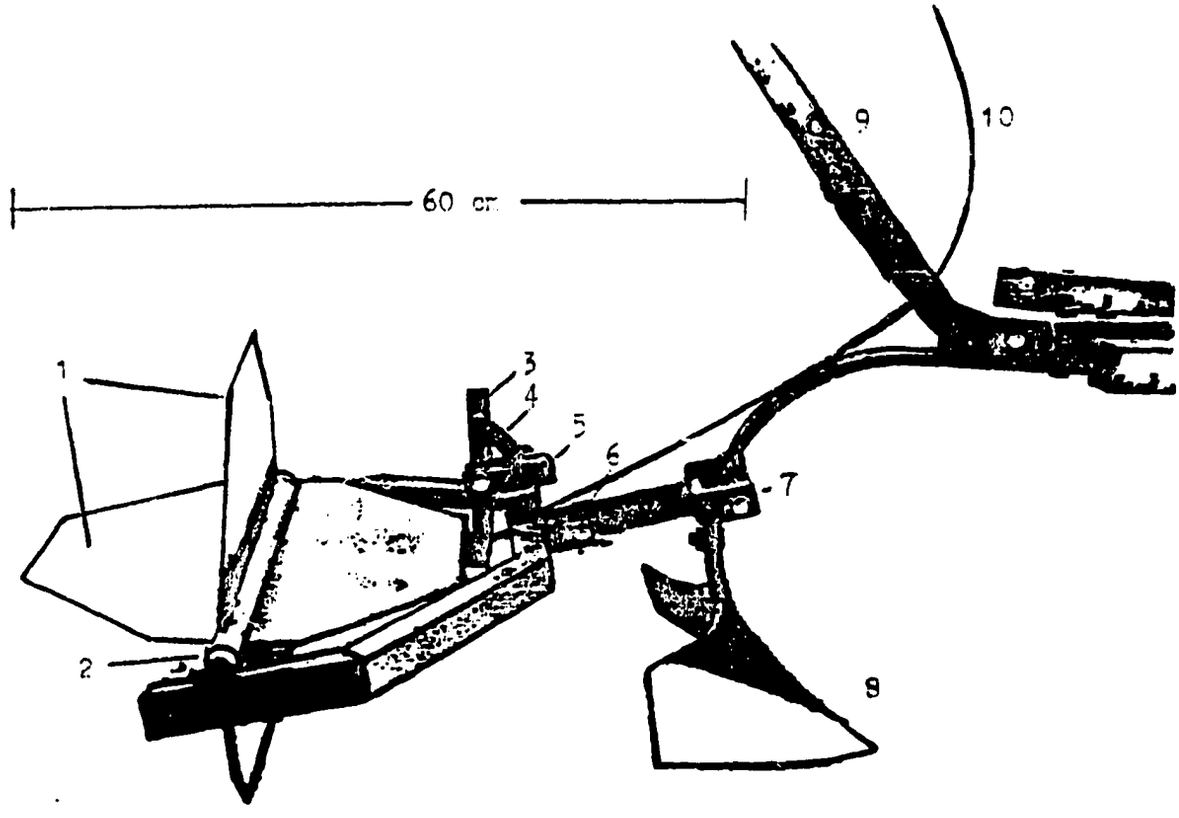

1. Shovels
2. Axel Bearing (Pipe)
3. Latch Lever
4. Rubber Band (Inner Tube Strip)
5. Latch Adjuster (for correct angle and to compensate for wear in bearings, shovels and latch).
6. Shovel angle Adjusting Bolt
7. Coupler
8. 30 cm Ridger that allows soil to flow over the top.
9. Handles of "houe Manga" (FAO donkey weeder)
10. Bicycle cable to Brake Lever

Fig 1. The IITA/SAFGRAD mechanical ridge tier (donkey version.).

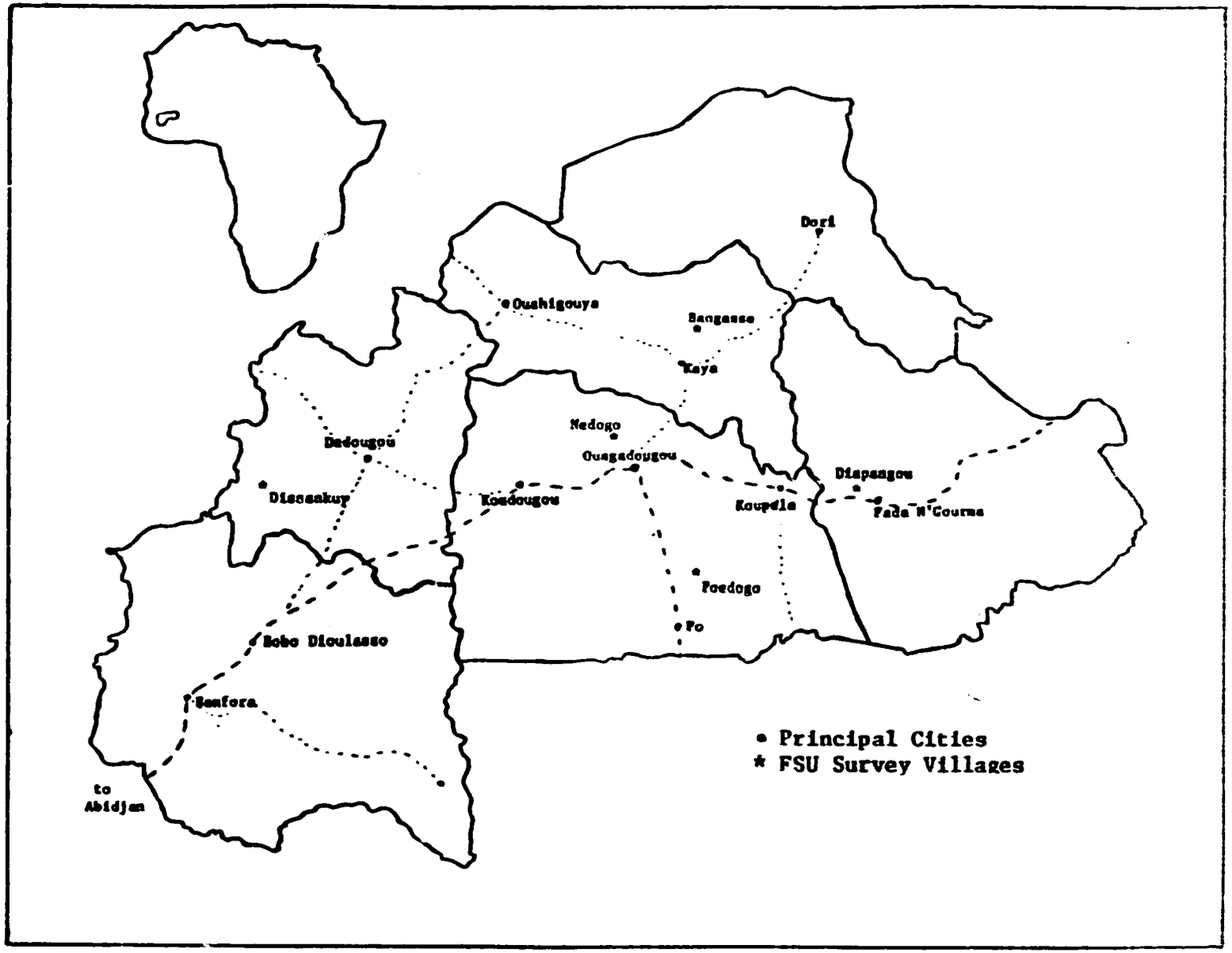

Figure 2: Map of Burkina Faso

The field trials conducted were on-farm farmer-managed trials. Previous research (Lang et al., 1984, and Ohm et al., 1985a and 1985b) indicated that both agronomic and economic results were the most favorable when the two technologies of tied ridging and fertilizer were used in combination. Thus all treatments received 100 kg/ha 14-23-15 fertilizer applied in a band 10-15 cm from the crop rows 2 to 3 weeks after planting plus 50 kg/ha of urea applied in a band 10-15 cm from the crop rows 6 to 8 weeks after planting. The treatments were as follows:

1) traditional animal traction tillage practices (control),[3]
2) tying the animal traction-made ridges every 1 to 1.5 m by hand at second weeding (6 to 8 weeks after planting),
3) tying the ridges mechanically with the MRT at second weeding and,
4) tying the ridges mechanically with the MRT at first weeding (3 to 4 weeks after planting) and again at second weeding.

The purpose of doing Treatment 4 was twofold. First, constructing tied ridges closer to planting should be more beneficial however, the plants are not very large at the first weeding period and this treatment enabled the assessment of any damage done to the young plants. Secondly, if tied ridges are to be made in the first weeding period, the ties will have to be broken at the second weeding/ridging period and therefore the ties will have to be made over again. Therefore, Treatment 4 allows an assessment of the profitability of tying the ridges twice as compared to once in Treatment 3 and also assesses whether the farmers had problems in constructing ties in the second weeding period because of the presence of the first weeding ties.

Farmers managed and carried out the experiments and were responsible for all labor inputs. Fertilizer was supplied to the farmers. Local sorghum varieties were used. Prior to seeding, the field staff delineated each parcel with colored stakes and measured the area of all parcels. Parcel size ranged from 0.05 to 0.12 ha depending on the size of the farmers' field. Prior to harvest, all parcels were evaluated for general conditions of the crop. Farmers harvested all parcels and the field staff weighed the harvest.

Field plots were chosen using the following criteria: at least a 1% slope, no previous mineral fertilization and homogeneity in soil structure, texture and type for all treatments within a block (soils are predominantly sandy-clay).

Labor inputs associated with the MRT were obtained by the field staff on a farmer recall basis (within one week after use of the MRT). A farmer questionnaire was conducted just prior to harvest to obtain the farmers' opinions, problems and suggestions.

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[3]Traditional animal traction tillage practices generally include weeding with a cultivator (Houe Manga) at the first weeding period (3 to 4 weeks after planting) and at the second weeding/ridging period (6 to 8 weeks after planting). At second weeding, the cultivator is equipped with a wide middle sweep that places soil at the base of the plants to keep them from lodging.

Objectives 1 and 2 were unable to be met at Diapangou or Poedogo because of field staff shortages.[4] The farmers that did the trials in Diapangou did most operations later than the protocol called for and the trials were abandoned. The trials in Poedogo were not abandoned but there was insufficient data on all treatments to conduct a statistical analysis. However, the findings and the problems experienced in Poedogo are discussed in the text. Thus only agronomic data and an economic analysis from the trials at Nedogo are presented. The farmer questionnaire was conducted in all three villages.

THE NEDOGO TRIALS

General Crop and Field Conditions. At Nedogo, the total rainfall received in 1985 of 572 mm was below the long term average of 809 mm (Fig. 3) and below the 670 mm received in 1983 but higher than the 452 mm received in 1984. Seeding of millet and sorghum crops began in mid-June. Crop establishment was excellent and little replanting was necessary. A 17-day dry spell in August at the time of peak flowering severely reduced maize yield. Millet and sorghum crops showed only minor drought stress symptoms and were not adversely affected. In mid-September, sorghum reached 50% flower under ideal field conditions. Millet began flowering in late September. The last good rain fell on 1 October allowing both sorghum and millet to complete grain fill before soil moisture reserves were exhausted. Maize, sorghum and millet yields were estimated by the field staff to be 60%, 100% and 100% of normal respectively.

Description. The experimental design was a split-plot with whole-plots (types of traction) arranged in a completely randomized design and treatments were subplots. The four treatments were presented in the Introduction. Seven farmers with mono-donkey traction and seven farmers with mono-ox traction did all the treatments according to the protocol. The smaller donkey MRT was used by both donkey and ox traction farmers. Both ridging and tying were done simultaneously in one pass in Nedogo. On average, the ties made with the MRT were about 13 cm high whereas the ties made manually were about 15 cm in height and had a broader base. There was little difference in the height of the MRT ties between donkey or ox traction. An oversized triangular weeding sweep 15 cm in width was used on the cultivator in place of the normal 30 cm wide sweep because the large sweep cleaned out the furrow too well and did not leave enough soil for the MRT to scrape up and form ties.

Results and Discussion. All three treatments consisting of tied ridging resulted in significant yield increases over the control (Table 1). Increases in yield from the tied ridging treatments over that of the control ranged from 18% to 29%. Given the distribution and timeliness of the rains, the yields of the tied ridging treatments were not dramatically higher than the yield of the control. This is in contrast to the Nedogo donkey traction sorghum trials in 1983 and 1984 (Ohm et al., 1985b). Treatments where ridges were tied by hand out-yielded the fertilized only treatments by 60% in 1983 and 118% in 1984. In 1984 less rainfall was received than in 1985 and although the 1983 rainfall was higher than in 1985, the distribution and timeliness was not as good for crop growing conditions.

[4]This was the first operational year for the newly formed national farming systems program in Burkina. In 1985, FSU took on an advisory role and transferred its staff to IBRAZ and relied on the IBRAZ staff for all the field work. The demands put on the limited number of IBRAZ field staff in this first year of operation were substantial.

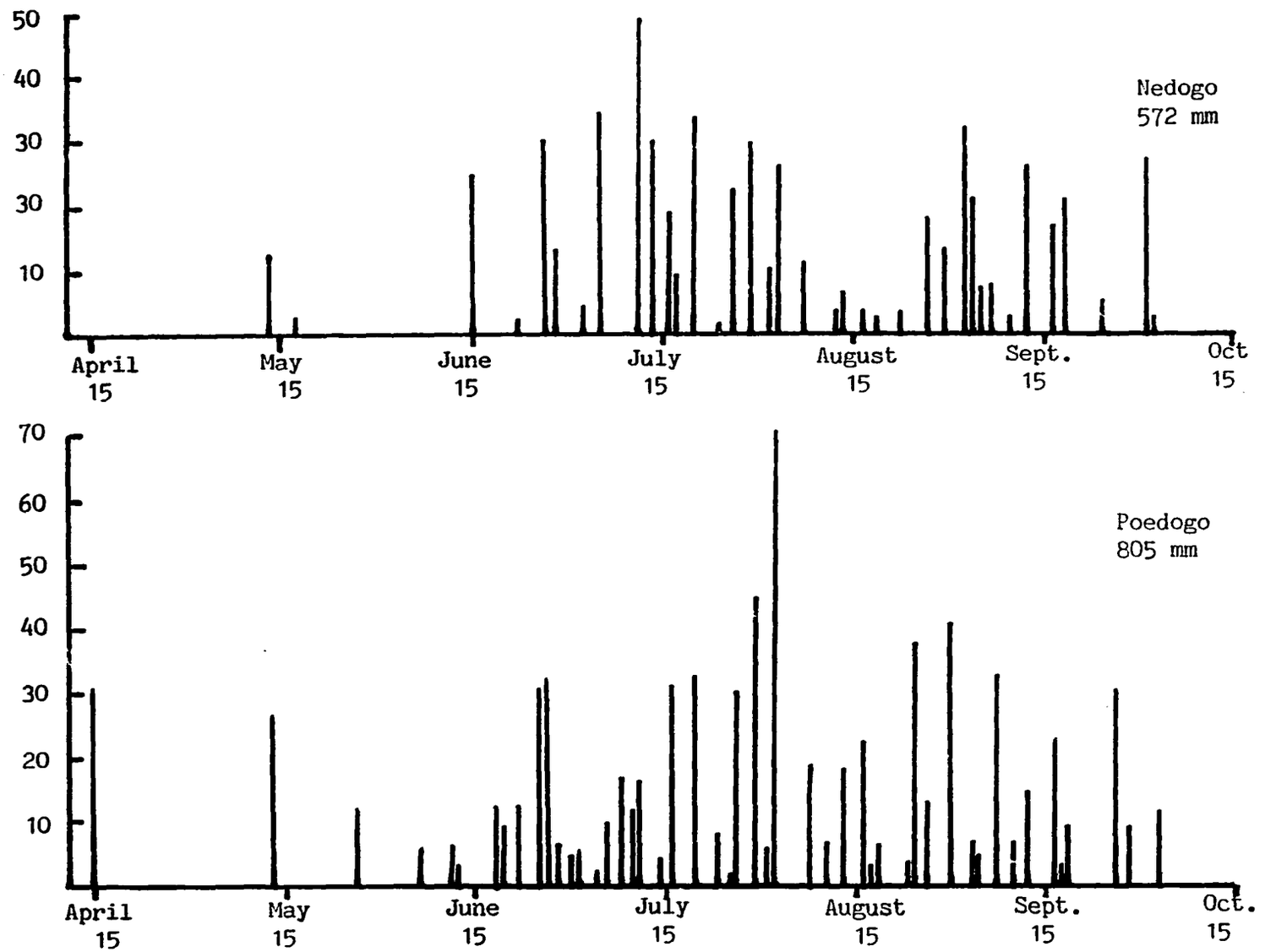

Fig. 3. Daily rainfall for the two village sites of Nedogo and Poedogo in Burkina Faso, 1985. Long term average annual rainfall at data collection sites near Nedogo (Pabre) is 809 mm (1952 to 1975) and at Poedogo (Manga) is 905 mm (1947 to 1975) (ICRISAT, In Press).

Table 1. Means for effects of animal traction and for three methods of tied ridging at Nedogo, 1985.

Treatments[1]	Mean Grain Yield
	kg/ha
Traction - MRT[2]	
Donkey	920.5
Ox	882.6
SE[3]	71.6
Tied Ridging Methods[4]	
Control[5]	740.0
TR-Manual[6]	954.4
MRT-1[7]	875.6
MRT-2[8]	927.5
SE[3]	62.8
CV%	19.0
N[9]	14

[1]Local varieties of sorghum were used.

[2]Comparing the mechanical tying of ridges by donkey traction with the mechanical tying of ridges with ox traction.

[3]Standard Error of the difference between two treatment means.

[4]Fertilizer application of 100 kg/ha 14-23-15 in a band 10 to 15 cm from the rows of sorghum 3 to 4 weeks after planting and 50 kg/ha urea applied in a band 10 to 15 cm from the rows of sorghum 6 to 8 weeks after planting was applied to all treatments.

[5]Flat cultivation without tied ridges.

[6]Manually tying the ridges made by animal traction 6 to 8 weeks after planting.

[7]Mechanically tying the ridges 6 to 8 weeks after planting.

[8]Mechanically tying the ridges 3 to 4 weeks after planting and again at 6 to 8 weeks after planting.

[9]The number of farmers' fields (replications) on which the experiment was grown - 7 farmers with donkey and 7 farmers with ox traction.

The three ridging treatments did not significantly differ. The yield however tended to be higher when the ridges were tied manually (TR-Manual) as compared to those tied with the MRT. The lower yields observed in the two treatments using the MRT may be the result of root pruning or the damage caused to the plants by the MRT. To overcome this problem, the width of the MRT should be made shorter or the rows wider by about 5 cm keeping in mind that the operation must deposit enough soil at the base of the plants at second weeding to keep them from lodging. Also, the higher ties of the manually constructed tied ridges may have allowed more water to accumulate during a rain thus creating a larger moisture reserve. Yields in Treatment MRT-2 where the MRT was used at both first and second weeding was not significantly different from yields obtained in Treatment MRT-1 where the MRT was used at second weeding only. The timely and adequate rains (228.3 mm in July alone) made the yield difference minimal between the two treatments.

No difference in sorghum yields between mechanically tying the ridges with ox traction and mechanically tying the ridges with donkey traction were observed (Table 1). This is in concurrence with the field staff observations that there was little difference between the height of the MRT (donkey version) ties when using donkey or ox traction.

THE POEDOGO TRIALS

General Crop and Field Conditions. At Poedogo, the total rainfall received in 1985 of 805 mm was below the long term average of 905 mm (Fig 3) but higher than the 1984 average of 633 mm. Seeding of millet and sorghum began in mid-May with some farmers seeding "dry" in the hopes of a good early rainfall. Plant establishment was poor and required at least one reseeding and in some cases two reseedings. The months of July and August were very wet (222.5 mm and 242.0 mm respectively) and farmers had difficulty getting into the fields. Soil moisture was not limiting during the agricultural season other than during the seeding period. Sorghum began to flower in early September under ideal field conditions. Maize, sorghum and millet yields were estimated by the field staff to be 120, 120 and 80% of normal, respectively.

Description. The protocol called for the same treatments as outlined in the Introduction. Initially, 15 farmers with donkey traction were to conduct the trials with the donkey version of the MRT. When constructing the ties with the MRT at first weeding, the 15 cm sweep was used on the cultivator and weeding and tying were done simultaneously in one pass. When constructing the ties with the MRT at second weeding, farmers did not like the smaller than normal ridges that the 15 cm sweep made. Farmers at Poedogo normally use a 30 cm sweep (a different type from that used in Nedogo) which makes very large ridges that support the plants from late season storms and subsequent lodging. The use of the large ridger combined with the MRT increased the draft to the point where it was too heavy for the donkeys do pull. Thus farmers did the operation in two passes by ridging with the large sweep in the first pass and then tying the ridge with the MRT attached to the cultivator with the 15 cm sweep for the second pass. The ties made by the MRT in the two pass method were on average 17 cm high compared to 13 cm for the one pass method and 15 cm when constructed manually.

Results and Discussion. Data was limited as few farmers completed all the treatments. Due to favorable weather conditions after planting and the very wet months of July and August, farmers had difficulty getting into

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the field and about half the farmers decided not to construct tied ridges because sufficient moisture existed. The shortage of field staff precluded any effort to get the farmers to do the trials. Given the adequate moisture in 1985, farmers would logically not construct tied ridges however an opportunity was lost to assess if in times of good rainfall, tied ridges could have an adverse effect on yields in the Poedogo area because of water logging and/or denitrification (adverse yield effects have been observed in some instances by IITA on some soil types). Field staff did observe however that the three tied ridging treatments tended to have the same relationship to each other as was observed in Nedogo.

ECONOMIC AND LABOR DATA ANALYSIS

A survey was conducted to obtain the labor demands required by the use of the MRT relative to that of tying the ridges by hand. Since farmers traditionally ridge, the variable of interest is the additional time required to construct the ties over and above that of ridging. The average amount of labor required for tying the ridges by hand after the ridges had been constructed for Treatment TR-Manual was 38.56 manhours/ha (N = 14) in Nedogo and 45.62 manhours/ha (N = 7) in Poedogo.[5] In Nedogo, when ridging and constructing tied ridges simultaneously with the MRT in one pass, farmers with donkey traction took on average 1.02 actual hours/ha (N = 6) more time than when the traditional ridging operation was performed alone. This is to be expected since the addition of the ridger increases the draft that the donkey must pull. Thus if two men performed the one pass MRT operation in Nedogo with donkey traction, it would require 2.04 manhours to construct tied ridges on one hectare in contrast to taking 38.56 manhours to tie the ridges by hand on one hectare; a saving of 36.51 manhours/ha. For ox traction farmers in Nedogo, an extra 0.43 actual hours/ha were required when the MRT was used in one pass.

In Poedogo, the survey results indicated that on average, farmers required an additional 3.34 (N = 6) actual hours to construct tied ridges in one pass with the MRT above that of traditionally constructing ridges alone. When the two pass method was used - ridging first, then tying the ridges with the MRT attached to the cultivator - the second pass to tie the ridges with the MRT required on average 13.74 actual hours/ha which still represents a substantial labor saving over that of tying the ridges by hand (discussions with the field staff indicated the 13.74 hrs/ha to be on the high side).

The gross revenue and net revenue figures on a CFA/ha basis are presented in the partial budget analysis in Table 2. The net revenue figures account for the cost/ha of fertilizer (13,868 CFA/ha) for all four Treatments and the annual cost/ha of the MRT (1,467 CFA/ha) for Treatments MRT-1 and MRT-2.[6] The net revenue/ha figures of all three tied ridging Treatments are all above the net revenue/ha figure of the Control and the

[5] A composite labor hour figure in terms of manhours/ha is calculated using the following weights: one male hour ($\geq$ 15 yrs) = 1, one female hour ($\geq$ 15 yrs) = .75 and one child hour ($<$ 15 yrs) = .5.

[6] The 1,467 CFA/ha cost of the MRT is calculated as 15,000 CFA total cost annualized over 5 years at 15% interest rate assuming the MRT is used on 3.0 ha/year.

difference is expressed in Table 2 as the net revenue gain/ha.[7] The net revenue gain/ha of the three tied ridging Treatments represent the net revenue gained solely because of the increased yield from the use of tied ridging. The net revenue gain/ha of using the MRT (Treatments MRT-1 and MRT-2) are below the net revenue gain/ha of tying the ridges by hand Treatment TR-Manual). The cost of the MRT and the lower yields observed in Treatments MRT-1 and MRT-2 contributed to the lower net revenue gain/ha relative to the TR-Manual Treatment.

The important fact however is that there is a labor constraint which precludes the tying of ridges manually on a significantly large hectarage per household.[8] Results from a linear programming model (LP) of a Nedogo representative farm indicated that family labor availability constrained the manual tying of tidges to 0.9 ha whereas, when given the option to use the MRT, family labor and donkey traction resources existed to profitably tie ridges on about 3.0 hectares (Nagy et al., 1985). Thus when the net revenue gain above the control is calculated using 0.9 ha as the maximum hectarage that can be tied under TR-Manual (0.9 x 10,700 CFA/ha) and 3.0 ha as the maximum hectarage that can be tied under MRT-1 (3.0 x 5,283 CFA/ha) and MRT-2 (3.0 x 7.883 CFA/ha), the MRT Treatments show net revenue gains to tied ridging that are larger than that of the net revenue gain under TR-Manual (Table 2). The use of the MRT therefore increases the number of hectares that can be profitably tied ridged given the labor resources of the farm and substantially increases the net revenue of the farm.[9] In the future, it may be expected that the yields obtained from the MRT Treatments will be similar to that obtained in Treatment TR-Manual once the equipment is improved and the farmers adapt the MRT technology

[7]Most of the agricultural labor is provided by the 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 critical times because a labor pool does not exist and farmers cannot be hired away from their own farm work at the average going wage of between 40 to 50 CFA/hr. Imperfections in the labor market account for the fact that the marginal product of labor is four to seven times the average wage rate in critical labor shortage periods (Roth et al., 1984). Thus the cost to hire sufficient labor for tying the ridges by hand for treatment TR-Manual would be between 160 to 350 CFA/hr. At a cost of 275 CFA/hr for labor, the net revenue gain/ha of treatment TR-Manual in Table 2 would be near zero.

[8]The FSU 1984 adoption of technology survey indicated that the average hectares of manual tied ridging construction was 0.32 at Nedogo (Ohm et al., 1985b). One farmer with a large household who embraced the idea of tied ridging was able to do one hectare. Farmers indicated that they would have liked to do more but could not because of the labor constraint.

[9]The 3.0 ha figure is for tied ridging with donkey traction and is reflected in the budget analysis of Table 2. Thus the net revenue figures would be larger in Table 2 if the Table was based on the number of hectares an ox could tied ridge with the MRT which would be larger because oxen can work longer hours and move faster.

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Table 2. Economic analysis of the mechanical ridge tier (MRT), 1985

	Treatments[1]			
	C	TR-Manual	MRT-1	MRT-2
Grain Yield, kg/ha	740	954	875	927
Yield Gain Above Control, kg/ha	-	214	135	187
Gross Revenue, CFA/ha[2]	37,000	47,700	43,750	46,350
Net Revenue, CFA/ha[3]	23,132	33,832	28,415	31,015
Net Revenue Gain Above Control, CFA/ha	-	10,700	5,283	7,883
Net Revenue Gain Above Control, CFA/ Area Tied Ridged[4]	-	9,630	15,849	23,649

[1]C= Control (traditional flat animal traction cultivation); TR-Manual = tying of animal traction made ridges manually at second weeding; MRT-1 = tying the ridges with the MRT at second weeding; MRT-2 = tying the ridges with the MRT at both first and second weeding. All treatments received 100 kg/ha of 14-23-15 applied at first weeding in a band 10-15 cm from crop rows and 50 kg/ha urea applied similarly at second weeding.

[2]Post harvest sorghum farm price of 50 CFA/kg x yield.

[3]Gross revenue minus fertilizer cost (90 CFA/kg for 14-23-15 and 78 CFA/kg for urea including 6 months interest charge of 15%) and minus yearly MRT cost 1,467 CFA/ha for treatments MRT-1 and MRT-2 (15,000 CFA total cost annualized over 5 years at 15% interest rate assuming the MRT is used on 3 ha/year).

[4]Based on the assumption that labor availability constrains manual tied ridging construction (TR-Manual) to 0.9 ha whereas labor and animal traction resources exist to construct 3.0 ha of tied ridging with the MRT in Treatments MRT-1 and MRT-2. Hectarage estimates are derived from a linear programming model (Table 6, Nagy et al., 1985).

thus making the difference in the net revenue and net revenue gains of the MRT larger.[10]

The 1985 data presented in Table 2 represent yields obtained under good weather conditions of an adequate and good distribution of rainfall throughout the cropping season. A good year such as 1985 however is not the norm. A survey of twenty Nedogo farmers indicated that a good distribution and rainfall year equal to or better than 1985 occurs about three years out of ten and that a poor year similar to the distribution and rainfall levels of 1984 also occurs three years out of ten. Thus the economic analysis presented in Table 2 is a good weather year scenario. In contrast, two poor weather year economic analysis scenarios are presented in Tables 3 and 4 using actual 1984 data for the Control and TR-Manual Treatments from the 1984 Nedogo donkey traction sorghum trials (Ohm et al., 1985b). Yields for the MRT-1 and MRT-2 Treatments in Tables 3 and 4 are hypothetical since the MRT was not used in 1984 however the yields bear a similar relationship to the yield of Treatment TR-Manual as was observed in the 1985 MRT trials. The partial budget analysis in Table 3 uses the same sorghum prices and fertilizer prices as those in Table 2 and reflects a poor weather year in which drought was a local phenomenon (hence the same sorghum price). Although the overall revenues in Table 3 are lower than those of Table 2, the difference in the net revenue gain in CFA/Area Tied Ridged for the MRT Treatments are much larger relative to that of the TR-Manual Treatment than for the corresponding figures in Table 2. The partial budget analysis in Table 4 reflects a poor weather year that is regional (as in 1984) and uses the 1984 sorghum price of 90 CFA/kg (prices were forced up because of the general drought). Both overall revenues and net revenue gains in this scenario are substantially larger than those of Table 2 as is the difference in the net revenue gains in CFA/Area Tied ridged between TR-Manual and the MRT Treatments.

Several conclusions can be drawn from the economic and labor data analysis. When using the one pass method with donkey traction, tying ridges with the MRT only requires 1 to 3.5 hours/ha of additional labor and substantially reduces the amount of labor required to construct tied ridges relative to that of tying the ridges by hand. Ox traction takes less time. Given the labor and time constraints, the MRT can be used to construct over three times as much tied ridging as can be tied by hand. The economic budget analysis indicates that the use of the MRT is very profitable for the farmer. The MRT was also found to be profitable under a range of both good and poor weather year scenarios.

SUMMARY OF RIDGE TYING MACHINE SURVEY

In October and November of 1985, farmers involved in the trials with the MRT were surveyed regarding their use of the machine as well as the problems they experienced. The survey was conducted in all three villages with MRT trials (Nedogo, Poedogo and Diapangou), after farmers had completed using the MRT at second weeding. A total of 43 households participated in the survey. The fifteen households in Nedogo included eight

[10] In the Nedogo MRT trial and in the two scenarios in Tables 3 and 4, the Control was fertilized. Had the Control not been fertilized, all the revenue figures above that of the Control would have been much larger in Tables 2 to 4.

Table 3. Scenario I, poor local weather year economic analysis of the mechanical ridge tier.

	Treatments[1]			
	C	TR-Manual	MRT-1	MRT-2
Grain Yield, kg/ha	355	773	750	750
Yield Gain Above Control, kg/ha	-	418	395	395
Gross Revenue, CFA/ha[2]	17,750	38,650	37,500	37,500
Net Revenue, CFA/ha[3]	3,882	24,782	22,165	22,165
Net Revenue Gain Above Control, CFA/ha	-	20,900	18,283	18,283
Net Revenue Gain Above Control, CFA/ Area Tied Ridged[4]	-	18,810	54,849	54,849

[1]Treatments correspond to those in Table 2, footnote 1. Yields for the control C and for manually tying the ridges (TR-Manual) are actual yields from the 1984 Nedogo donkey traction trials (Ohm et al., 1985b). Yields for MRT-1 and MRT-2 are hypothetical since the MRT was not used in the 1984 trials. The yields however bear a similar relationship to the yield of Treatment TR-Manual as was observed in the 1985 MRT trials.

[2]Post harvest sorghum farm price of 50 CFA/kg x yield.

[3]Gross revenue minus fertilizer cost (90 CFA/kg for 14-23-15 and 78 CFA/kg for urea including 6 months interest charge of 15%) and minus yearly MRT cost of 1,467 CFA/ha for treatments MRT-1 and MRT-2 (15,000 CFA total cost annualized over 5 years at 15% interest rate assuming the MRT used on 3 ha/year).

[4]Based on the assumption that labor availability constrains manual tied ridging construction (TR-Manual) to 0.9 ha whereas labor and animal traction resources exist to construct 3.0 ha of tied ridging with the MRT in Treatments MRT-1 and MRT-2. Hectarage estimates are derived from a linear programming model (Table 6, Nagy et al., 1985).

Table 4. Scenario II, poor regional weather year economic analysis of the mechanical ridge tier.

	Treatments[1]			
	C	TR-Manual	MRT-1	MRT-2
Grain Yield, kg/ha	355	773	750	750
Yield Gain Above Control, kg/ha	-	418	395	395
Gross Revenue, CFA/ha[2]	31,950	69,570	67,500	67,500
Net Revenue, CFA/ha[3]	18,082	55,702	52,165	52,165
Net Revenue Gain Above Control, CFA/ha	-	37,620	34,083	34,083
Net Revenue Gain Above Control, CFA/ Area Tied Ridged[4]	-	33,858	102,249	102,249

[1]Treatments correspond to those in Table 2, footnote 1. Yields for the control C and for manually tying the ridges (TR-Manual) are actual yields from the 1984 Nedogo donkey traction trials (Ohm et al., 1985b). Yields for for MRT-1 and MRT-2 are hypothetical since the MRT was not used in the 1984 trials. The yields however bear a similar relationship to the yield of Treatment TR-Manual as was observed in the 1985 MRT trials.

[2]Post harvest sorghum farm price of 90 CFA/kg x yield.

[3]Gross revenue minus fertilizer cost (90 CFA/kg for 14-23-15 and 78 CFA/kg for urea including 6 months interest charge of 15%) and minus yearly MRT cost of 1,467 CFA/ha for treatments MRT-1 and MRT-2 (15,000 CFA total cost annualized over 5 years at 15% interest rate assuming the MRT is used on 3 ha/year).

[4]Based on the assumption that labor availability constrains manual tied ridging construction (TR-Manual) to 0.9 ha whereas labor and animal traction resources exist to construct 3.0 ha of tied ridging with the MRT in Treatments MRT-1 and MRT-2. Hectarage estimates are derived from a linear programming model (Table 6, Nagy et al., 1985).

with donkey traction and seven with oxen traction. In Poedogo, seven donkey traction and two horse traction households were surveyed, and the 19 households in Diapangou included eleven with donkey traction and eight with oxen traction. It should be noted that none of the farmers in Diapangou completed the trials correctly, so their responses may reflect lack of experience. This will be evident in the discussion of farmers' problems with the machine. The regular donkey version of the MRT was used with donkey and mono-bovine traction in Nedogo, donkey and horse traction in Poedogo and donkey traction in Diapangou. A heavier version of the machine was used for bi-bovine traction in Diapangou.

The farmers were questioned about a number of possible problems with the machine. These included problems with the MRT itself, agronomic problems, and evaluation of the quality of tied made. One of the problems was the weight of the machine. Many farmers thought the machine was too heavy, and consequently too hard on the animal pulling it. This varied by type of animal traction and by village. In Nedogo most donkey users (80%) thought the machine was too heavy, but none of the farmers thought the machine was too heavy for oxen. In Poedogo, 63% of donkey users thought the machine was too heavy but horses did not have a problem. Most donkey users in Diapangou found the machine too heavy (82%), and unlike the other villages, oxen users also thought the machine was too heavy (88%). This is because oxen teams are used in Diapangou, and the machine that was adapted to this traction is substantially heavier than the regular donkey version.

Closely related to the problem of weight is the technique used in various villages. In Nedogo, one pass through the field was used at both first and second weeding, with the ridging and tying of ridges done simultaneously. The load on the animals could be lessened by doing ridging and tying in two separate passes. Forty percent of donkey users in Nedogo thought two passes would be better, especially at second weeding. Farmers with oxen, however, preferred one pass. Diapangou farmers used one pass through the field at both first and second weeding. About half the farmers using both types of traction thought that the two pass method was better because it was less tiring for the animal. However, a number of farmers expressed concern over the amount of time needed to do two passes, especially during first weeding when time is an important constraint. Regardless of their yes-no response to the question, most farmers expressed this animal fatigue-time constraint trade-off. The practices in Poedogo are somewhat different. The ridger (middle sweep) used at second weeding in Poedogo is subtantially bigger than elsewhere and the making of the large ridges increases the draft the animals must pull. In addition the soils are slightly heavier than in the other two villages. While the one pass method was used at first weeding in Poedogo, the draft of the MRT in addition to that of the ridger with the large middle sweep at second weeding was considered too heavy for one animal and all trials were done using two passes at second weeding. Most farmers surveyed (89%) thought the two pass method would be better to use at first weeding, and all farmers preferred two passes at second weeding.

When farmers were asked how many hours per day their animals could work with the ridge tier (using one pass in Nedogo and Diapangou, and two passes in Poedogo), they responded as follows:

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	Donkey	Oxen	Horse
Nedogo	2.3	4.7	
Diapangou	2.0	2.3	
Poedogo	3.4		4.8

As can be seen, oxen or horses have a substantial advantage over donkeys when the lighter version of the machine is used, although using two passes increases the amount of time that donkeys can work at tying.

In general, farmers did not have problems with the machine breaking down. Only 16% of the farmers reported minor problems with the brake cable or cable cover, and with the rubber "spring" on the paddle release.

Farmers stated that the machine was easy to learn to use, most farmers taking less than 15 minutes to become familiar with the machine. Only three farmers expressed problems learning to use the machine, and these problems were related to their animals rather than the machine itself. One farmer was not familiar with animal traction and one farmer had a poorly trained animal.

One agronomic problem discussed involved the size of plants at first weeding and tying. Two-thirds of the farmers in Nedogo thought the plants were too small to do weeding and tying at first weeding. However, none of the farmers in the other two villages agreed with that. It is unclear what the problem might be in Nedogo, since only a small triangular piece and not a full-sized ridger is used with the tier at first weeding. In Diapangou several farmers said that the plants were too big at second weeding, and that the plants broke in turning the machine. However, second weeding of all trials was done late in Diapangou, if at all, hence the plants were bigger than they should have been. This emphasizes the importance of timing in the ridge tying process.

Finally, farmers were asked about the quality of the ties made by machine. Only one-third of the farmers thought ties made by hand were better than those made with the machine. Again, most of those farmers qualified their response with a concern over the amount of time required to make ties by hand, concluding that the quality loss was more than offset by the gain in time. A few farmers in Poedogo and Diapangou stated that the ties erode after consecutive rains, and machine tied ridges were slightly worse than hand tied ridges. This problem was most serious in Poedogo, the village with the highest rainfall, where three out of the six farmers who responded found that machine-made ties eroded more readily in the rain. Only one farmer out of seven had the same problem with hand-made ties.

Besides problems with the machine, farmers discussed how they would use the machine. Crops on which farmers would use the tied ridging machine are as follows:

	1st Choice			2nd Choice			3rd Choice	
	Millet	Sorghum	Maize	Millet	Sorghum	Maize	Millet	Maize
Nedogo	4	11	0	9	4	2	2	12
Diapangou	9	2	7	4	5	4	0	1
Poedogo	8	1	0	1	0	0	0	0

.../...

In general, both sorghum and millet are considered good prospective crops on which to use the machine. In Nedogo and Diapangou, maize is also important. A general lack of response on 2nd and 3rd choices in Poedogo makes any conclusions there difficult. When asked on what crops they would specifically not use the machine, farmers in Diapangou and Nedogo responded overwhelmingly with peanuts. Also mentioned were cowpeas, bambara nuts, and soybeans (in Diapangou). When the response was explained, most farmers said that these crops were planted with density and spacing that was not appropriate for the machine. Many farmers in Diapangou also mentioned that they would not use the MRT on sorghum that was planted in the low-lying areas (bas-fonds) which already hold water.

The final questions on the survey asked whether the farmer would continue to use the machine next year, and whether he would buy a machine for himself if it cost 15,000 CFA. Nearly every farmer (95%) responded that he would continue to use the machine the following year. When asked if they would buy the machine, however, farmers were somewhat more cautious. In Nedogo, where the trials were completed most successfully, all 15 farmers said they would buy the machine, although two modified the response to "if I had the money". In Poedogo, seven out of nine farmers would buy the machine. One who would not said he wanted to see the results of another year first. Six of the eleven donkey users in Diapangou would buy the machine, three if they had money and one if reasonable credit was available. Of the farmers who would not buy, three indicated they would buy the machine if it cost half as much, or 7500 CFA. the machine was least popular among oxen farmers in Diapangou. Only three out of eight people indicated they would buy, and all these farmers said only if reasonable credit was available. Four farmers indicated they would be interested if the machine cost 7500 CFA. Overall, 72% of the farmers surveyed in the three villages said they would buy the machine at 15,000 CFA, possibly only if reasonable credit was available. Several other farmers would be interested if the machine was cheaper.

FIELD STAFF OBSERVATIONS

Field staff observations were in general agreement with the results from the farmer questionnaire and many of their comments have been incorporated into the text of the study thus far. They did observe however, that older farmers found it difficult to trip the paddle and lock it back in time to make a proper tie. Also, farmers found it difficult to turn around at the end of the rows because of the awkward weight displacement of the MRT. This was particularly true for the larger ox traction version of the MRT. The farmers, however, were able to manage as they gained experience with the MRT. They observed that in general, farmers were very quick to learn how to operate the MRT. They also observed that farmers did not have any problems in ridging or tied ridging with the MRT at second weeding in Treatment MRT-2 where the tied ridges that were made at first weeding had to be broken and gone over.

A problem of the adaptability (proper attachment) of the MRT arose with ox traction farmers using the HVO2-B plow, the Hoe Fada or the Charrue Verte. Modifications of the attachment apparatus of the MRT had to be made in the field but could be improved upon. The attachment apparatus either needs to be universal or several types must be made available to fit the various cultivators and plows that the farmers use.

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The field staff observed that the MRT performed well across all types of soil except those heavy in clay. The best tied ridges were made on sandy loams or loamy sands. To make better tied ridges on soil with heavy clay, adjustments can be made to increase the angle at which the MRT cuts into the ground so that sufficient soil is available for the tie. This however significantly increases the draft.

SUMMARY OF ADOPTION SURVEY FOR RIDGE TYING MACHINE

In November 1985, a survey was conducted to determine the extent to which the ridge tying machine had been adopted by FSU cooperator farmers in Nedogo on their own land. This cropping season was the first time these machines had been used in Burkina Faso, so adoptors were simultaneously using the machine for the first time on farmer-managed trials and using it on their own fields. Sixteen farmers were given machines and participated in the trials. Of these sixteen, seven farmers (43.8%) used the machine to tie ridges on their own fields. The technology was used on a total area of 2.14 hectares or an average of 0.31 hectares per farmer. Of this total, 0.84 hectares were on millet and 1.30 hectares were on white sorghum. In addition, two farmers used small amounts of urea fertilizer. Six of the adoptors used oxen traction and the remaining farmer used donkey traction to pull the MRT.

By way of comparison, a 1984 survey found that 17 (24.6%) out of 69 farmer cooperators in Nedogo were using hand-tied ridges on an average of 0.31 hectares per farmer (Ohm et al., 1985b). This was the fourth year in which tied ridging trials had been done in Nedogo. A second survey to determine extent of adoption of hand-tied ridges has not been conducted in 1985, making direct comparisons impossible. Field staff were aware of a few farmers who used hand-tied ridges in Nedogo this year, but thought many farmers who had done hand tied ridges last year has switched to the machine this year. Considering the small number of farmers involved in the MRT trials, and the fact that this was the first year for the trial gives encouraging evidence that the machine will be adopted more rapidly than the time-consuming hand tied ridges. Regarding crop mix, 1984 results indicated that approximately 85% of the tied hectarage was on millet and 15% was on white sorghum (although some households were missing crop information). This again emphasizes the fact that farmers consider this a viable technology to be useful on millet as well as on the white sorghum which was stressed in the trials.

CONCLUSIONS AND RECOMMENDATIONS

The increased yields from tied ridging as noted in the Nedogo trials support the findings from previous FSU field campaigns. The MRT is profitable for farmers to use and the increase in yield more than pays for the cost of the MRT under various scenarios of good and poor weather conditions. The labor savings from the use of the MRT over that of tying the ridges by hand are substantial even if the second pass method is used. Ridging and tying in one pass represents the best method of saving labor although a number of farmers thought the machine was too heavy to use in one pass. Because of the labor savings, the MRT enables farmers to tie ridges on a larger proportion of their land relative to that being tied by hand, substantially increasing grain production and net revenue of the farm. Most farmers expressed an interest in continuing with the machine, for use on millet as well as sorghum, at the 15,000 CFA price - given that credit was available.

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The yields from the two MRT Treatments were slightly lower than the yields of the Treatment where the ridges were tied by hand. Particular attention must be given to row width so that the MRT does not prune the roots and also allows for maneuverability within the row so as not to damage the plants, keeping in mind that the purpose of ridging at second weeding is to support the plants against lodging.

Although the ties made by the donkey version of the MRT were marginally lower and had a smaller base than those tied by hand, they did stand up to erosion very well especially in a year of good rainfall. Ties made with the larger ox version of the MRT and pulled by two oxen, made ties comparable to that of the ties made by hand.

Further work is required to establish the geographical areas within Burkina (as well as within the region) that are suited to tied ridging and under what circumstances the soils are suitable so that recommendations can be made to the Extension System. The research already performed by IBRAZ, IRAT, IITA, ICRISAT and FSU with respect to soils and tied ridging provides a base to make recommendations.

Future research on mechanical ridge tiers such as the MRT needs to consider the following: 1) reducing the weight and awkardness of the machine without reducing its effectiveness while striving for a machine that ridges and simultaneously ties the ridge in one pass, 2) design studies to increase the adaptability of the machine across a wide range of cultivator/plow equipment now being used, and 3) the possibility of an automatic tripping device for machines like the MRT.

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