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AGRICULTURAL TECHNOLOGY IMPROVEMENT PROJECT

(ATIP)

PROGRESS REPORT

1988-1989 TILLAGE SYSTEMS TRIAL
(RESEARCHER MANAGED/RESEARCHER IMPLEMENTED)

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1988-1989 TILLAGE SYSTEMS TRIAL
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INTRODUCTION

These trials were a collaborative effort between DAR, ALDEP, ATIP, INTSORMIL and the SACCAR Land and Water Management Project. They were similar to the Collaborative Tillage Trials performed by ATIP and DAR in 1985-1987. The main differences between the current trials and previous ones, within the Francistown region, were that the recent trials:

(a). Included a modified deep-ripping treatment;
(b). Were truly national in scope;
(c). Included participation by more research and extension groups;
(d). A soil physicist was assisting in quantifying the physical effects of the different tillage practices on soil characteristics.

The trial design was agreed to by representatives of all the groups involved, in a meeting at Sebele on 1st August, 1988. Objectives, justification and approach were written by Dr. N. Persaud and are included below. The only variation that occurred in the Francistown region was that at one location a sixth treatment was included. This treatment was "skip row planting". Skip row planting is planting two rows of sorghum on 75 cm between-row spacings, and then leaving an adjacent area of 1.5 m empty.

OBJECTIVES

The objectives of this RHRI testing stage work were:

(a). To evaluate the performance of the deep-ripping system on seedbed and rootbed preparation, on yields, on soil moisture conservation, and to use it on various soils and under different rainfall conditions.

(b). To evaluate the effects of several possible improved tillage options on sorghum yields, seedbed and rootbed conditions during the growing season, and their effects on various soils and for different rainfall conditions.

JUSTIFICATION

Primary and secondary tillage are essential operations to ensure proper physical seedbed and rootbed conditions for sorghum establishment and growth, and for weed control on the soils of Eastern Botswana. Previous studies on sorghum yield response to tillage (mainly on-station by the DLFRS and on-farm by ATIP) have shown:

(a). All else remaining equal, the deeper the tillage, the higher the yield.

(b). Response to tillage is governed by the seasonal rainfall pattern.

(c). Response to tillage is influenced by any soil management factor, such as weed control operations, that directly affects soil profile moisture content.

(d). That over several years, the deep-ripping tillage system may have potential to increase yields.

(e). That two primary ploughing operations, the first early in summer and the second at a later date, depending on the rainfall, may provide economic yield benefits over the conventional single plough/plant operation.

More tillage studies were needed to develop a fundamental understanding of the sorghum crop responses to tillage. Specifically the following needed to be evaluated:

(a). The direct influence of various tillage practices on soil physical properties over time.
(b). Sorghum yield response to these tillage practices for various soil types and seasonal rainfall patterns.

APPROACH

TREATMENTS: Proposed treatments were as follows:

(a). Conventional tillage: single plough/row planting operation.
(b). Double ploughing: a first ploughing done as early as possible, followed by a plough/row planting operation simultaneously with treatment (a).
(c). Deep-ripping: deep-ripping, when soil was dry, followed by a discing/row planting operation performed simultaneously with treatments (a) and (b), with 150 cm between rows.
(d). Conventional tillage with wide row spacing: same as in treatment (a) but with rows spaced as for the deep-ripping treatment.
(e). Ploughing and cultivation: as in treatment (b), but with the second tillage replaced with a cultivation/row planting operation.

DESIGN AND FIELD LAYOUT: Experimental plots were laid out in randomized, complete blocks with two blocks at each location. Experimental plots were 40 metres long by 15 metres wide, with a 10 metre allowance at each end for turning.

LOCATIONS: Locations were as follows:

(a). Sebele: one site
(b). Mahalapye: three sites
(c). Francistown: two sites at Mathangwane.

MEASUREMENTS:

(a). Site characterization: location and landscape characterization of each site using 9x9 panchromatic 1:50000 aerial photographs. Profile description of each site using the guidelines for soil profile description developed for Botswana by the FAO/UNDP/GOB Soil Mapping and Advisory Services Project. In situ bulk density measurements, sampling and chemical analyses on samples from all horizons to 125 cm. Surface bulk density sampling at 0-5, 0-10, and 0-15 cm depth intervals for each elementary plot for all sites.

(b). Physical measurements: profile soil moisture, bulk density at 0-5, 0-10, and 0-15 cm depths.

(c). Meteorological measurements: non-recording rain gauges installed at each site.

(d). Crop measurements: observations on plant stands, weed counts, plant height, stand density at harvest, and crop yields made at appropriate times during the growth of the crop.

(e). All labour and input data were collected so that economic comparisons could be made between the different technologies.

SPECIFIC MEASUREMENT ISSUES AND RESULTS

This trial was performed at one location in Mathangwane village, the Tutume Agricultural District. A second trial was planted twice. The first time it was destroyed by rats; the second time by drought immediately following planting. After this it was abandoned, due to the lateness of the season. The daily rainfall amounts for the surviving location are given in Appendix 1. During implementation of the treatments, there were some deviations from the original plan. These are described below. The dates of all field operations, by treatment, are given in Table 1.

TABLE 1: DATES OF ALL FIELD OPERATIONS, BY PLOT, NATIONAL TILLAGE TRIAL, LOCATION 1, FRANCISTOWN REGION, 1988-1989

OPERATION	TREATMENT		
	CONVENTIONAL	DOUBLE PLOUGH	DEEP-RIP
	DATE		
DEEP-RIP	-	-	7.9.88
HARROW/BED-SHAPE	-	-	7.9.88
PRELIMINARY PLOUGHING	-	31.10.88	-
PLOUGHING	19.12.88	19.12.88	19.12.88
ROW PLANTING	19.12.88	19.12.88	19.12.88
THINNING	10. 2.89	10. 2.89	10. 2.89
WEEDING	11/12.2.89	11. 2.89	11/12.2.89
HARVEST	11. 5.89	11. 5.89	11. 5.89
	PLOUGH-CULTIVATE	CONVENTIONAL & WIDE ROW SPACING	SKIP ROW PLANTING
DEEP-RIP	-	-	-
HARROW/BED SHAPE	-	-	-
PRELIMINARY PLOUGHING	31.10.88	-	31.10.88
PLOUGHING	19.12.88	19.12.88	19.12.88
ROW PLANTING	19.12.88	19.12.88	19.12.88
THINNING	10. 2.89	10. 2.89	10. 2.89
WEEDING	11/12.2.89	11. 2.89	11. 2.89
HARVEST	11. 5.89	11. 5.89	11. 5.89

PRELIMINARY TILLAGE

The first tillage operation was deep-ripping. There were some logistical problems involved with this. First was the problem of finding a tractor with sufficient horse power to perform the operation (and sufficient height to lift the ripper). Normally tractors are hired in the village to perform tillage operations. However, the largest tractors for hire in Mathangwane village were 185's, and these did not have sufficient height or power. Finally, a large

tractor was secured from the local CTO in Francistown. Even this tractor (CA250) had to make two passes over each rip-line in order to achieve a ripping depth greater than 40 cm. The point here is that if ripping is to be recommended for this area, there must be some mechanism to account for the small size of tractors in the villages. In this treatment, fertilizer was applied during the ripping operation. Harrowing and bed-shaping were also completed on the same day. At the time of planting, these plots were to be machine weeded in such a way that the rip lines would remain visible. However, the proper equipment was not available at planting. As there was considerable weed growth on the plot, the decision was made to plough the plot instead. The ends of the rip lines were marked before ploughing so that planting could be done on the rip lines after ploughing. Hence the "deep-ripped" plots were first ripped and molded, then later ploughed on the date of planting.

Another problem occurred with the plough-cultivate operation. Because equipment had to be borrowed or hired, there was no cultivator available at planting time. In order to destroy weeds and not leave these plots bare, the treatments were simply reploughed and row planted.[1]

For the rest of the treatments, preliminary tillage and planting was implemented as planned. Plots were 15 m x 40 m in size. On each plot, 20 kg/ha of P_2O_5 were broadcast (as 2:3:2 compound fertilizer) and ploughed down during the first ploughing operation for each treatment. On the deep-rip treatments, phosphate fertilizer plus kraal manure were applied within the rip line, during the ripping operation. All plots were planted on the same day, using a "Master" rotary injection planter (hand pulled). Sorghum (v. Segaolane) was planted. All rows were later thinned by hand (perhaps excessively). Final plant densities achieved are given in Table 2.

TABLE 2: PLANT STANDS, HEAD NUMBER AND POTENTIAL GRAIN YIELDS, BY PLOT, NATIONAL TILLAGE TRIAL, LOCATION ONE, FRANCISTOWN REGION, 1988-1989

PLOT	REP	TMT[a]	NO. OF PLANTS PER HA(X1000)	HEADS PER PLANT	YIELD (KG/HA)
101	1	5	13.9	1.57	639
102	1	4	21.5	1.36	663
103	1	6	18.8	1.51	851
104	1	2	19.5	1.66	1000
105	1	3	23.4	1.33	541
106	1	1	27.3	1.31	829
201	2	6	16.2	1.46	745
202	2	1	25.9	1.39	791
203	2	2	29.1	1.49	1066
204	2	3	21.7	1.98	917
205	[illegible]	4	33.2	1.51	1289
206	2	5	12.7	1.68	405

a. Treatments: 1 = Conventional; 2 = Double ploughing; 3 = Deep-rip; 4 = Plough/cultivate; 5 = Conventional with wide rows; 6 = Skip row planting (with double ploughing).

1. That is, exactly like the double-ploughing treatment plots. Thus the "plough-cultivate" treatment cannot be considered as different from the double ploughing treatment.

In the end, plant densities were estimated by counting the plants in 10 x 2 m segments of two rows each, per plot. Average row width was calculated by counting the number of rows per plot. Quadrat area was then calculated as twice the row width x 2 m row lengths. Plants/quadrat was then multiplied by the number of quadrats per hectare.

SOIL MOISTURE

Monitoring of soil moisture and bulk density throughout the season was done by a field assistant under the nominal direction of the soil physicist at Sebele. Direct training and supervision was actually conducted by the ALDEP Officer coordinating the Tillage Trials nationwide. These data were collected as prescribed, and are reported elsewhere (see ALDEP and INTSORMIL Reports). Estimates of soil moisture infiltration rates were not collected. The data on soil moisture levels and bulk density did not show any consistent relationship to grain yield. It is possible that there were systematic errors in the data collection system.

WEEDING

Weeding was done once per plot, by handhoe, immediately after thinning. This was sufficient to keep the plots largely weed free almost to harvest. Weeding labour time (person hours per plot) was measured by stop watch for each plot, as were all other labour-requiring operations, except harvest.

As soon as the crop had set grain, a person was hired to keep the birds away from the heads. There was very little bird damage on these plots.

HARVEST

Harvesting was done according to instructions provided in the harvest data collection field book (see Appendix 2). Grain samples were harvested by hand (20 samples per plot). In plot 106 there was an ant hill approximately 5 m x 5 m in size which caused considerable stunting of plants. This was avoided during harvest sampling by taking sample numbers 5, 6 and 7 from row 7 instead of row 5. Otherwise all sampling was done according to plan. Harvested samples were dried in the paper harvest bags (open) for three days, then threshed by hand. Grain samples were weighed on a triple beam balance accurate to 0.1 grams. Heads which had lodged prior to harvest were cut and stooked upright in the plot until the harvest date. At harvest, a random sample of 20 of these heads was collected and treated in the same manner as sample heads from the quadrats. From these, an estimate of head weight was applied to green heads grazed prior to the same date. Applying this estimate may have upwardly biased the estimates of treatment grain yield per hectare, because heads still green on the harvest sampling date might never have matured. However, this bias would have been slight because the average number of green heads per quadrat was never greater than 0.6 heads per quadrat, and was generally closer to 0.25. Average row spacing per plot was used to estimate quadrat area, which in turn was used to estimate grain yield per hectare (from grain yield per quadrat).

PLANT DENSITY AND GRAIN YIELD RESULTS

Plant stand densities and grain yields for each plot are presented in Table 2. Analysis of variance for each of the above variables was performed on an Apple

IIe microcomputer using the Daisy Professional package for a two-way analysis of variance. It was also performed with the MSTAT package on an IBM compatible microcomputer. These analyses showed no significant differences between treatments or replications for either variable. The lack of significant differences was possibly due to the high variability within treatments and the low number of replications.

A plot map of the experiment is shown in Appendix 3. A study of grain yields relative to plot location suggested that there may have been a soil gradient within the experiment that was not blocked out by the arrangement of replications. This examination showed that the six highest plot grain yields came from plots on the extreme north and north-eastern sections of the experiment. Other factors may have also been involved. The treatment layout (within replications) was determined by the use of a random number table. By chance, most of the early ploughed treatments were situated in the north and north-western sections of the experiment. However, the deep-ripping treatment, plot 204 (in the north-western corner of the experiment) gave a 70 percent higher grain yield than the same treatment in plot 105 (in the eastern-central section of the experiment) even though both had similar plant stand densities. A careful examination of soil characteristics (especially texture, fertility and moisture holding capacity) should assist in determining whether the observed relationship between plot location and grain yield was due to chance or to differences in soil characteristics.

Regarding the effects of plant stand densities on grain yield, it was true that the two highest yielding plots also had the highest plant stand densities. However, plant stand densities alone could not explain all of the variations among treatment mean grain yields. For example, the deep-ripping treatment had a mean stand density of 22,565 plants per hectare, and a mean grain yield of 731.5 kg/ha. When this is compared with the means for the skip row treatment (16,792 plants/ha and 752.1 kg/ha of grain) and the double plough treatment (24,329 plants/ha and 1067.5 kg/ha of grain), it is clear that something other than plant stand density was affecting treatment mean yields. Presumably the other factors were treatment effects and possibly soil physical factors.

LABOUR USE AND RETURNS

Labour data were collected for all of the operations and are reported in Appendix 4. Total labour per hectare varied from a low of 94 hours average for single ploughed, wide row spacing, row planted plots to a high of 161 hours average for double ploughed, row planted plots (Table 3). The deep-ripped plots required the most weeding time, with the double ploughed plots requiring the second most weeding. The high weeding labour requirement for the deep-ripped plots is consistent with earlier findings, but the relatively high investment in weeding labour for the DP plots is not consistent with prior years. On the other hand, the plough/cultivate system was also implemented as a DP system (due to implementation problems) and required slightly less weeding time than the SP system. As would be expected the initial ploughings, using a tractor, were fairly consistent, and harvesting/threshing time was related to yield.

Average returns per hectare and per hour of labour are reported in Table 4 with a complete set of data included in Appendix 5. The double ploughed system produced the highest net returns per hectare (P249.00), over three and one-half times as much as the single ploughing, wide row system which returned (P69.00 per hectare). The second highest return per hectare (P224.00) was the plough/cultivate system, implemented as DP. The net return for labour was the same for the single plough and double plough systems. Both were 109 percent

greater than the single ploughing, wide row system. All of the systems produced a net return to labour over P0.74.

TABLE 3: AVERAGE LABOUR TIMES, PERSON HOURS PER HECTARE, NATIONAL TILLAGE TRIAL, FRANCISTOWN AREA, 1988-1989[1]

REP	YIELD KG/HAa	FIRST PLOUGH	DEEP-RIPPING	FERT	PLOUGH	ROW PLANT	THIN	WEEDING	HARVEST THRESH	TOTAL TIME
SINGLE PLOUGH-RP	810			1.9	3.9	6.0	11.9	23.7	81.0	128.4
DOUBLE PLOUGH-RP	1033	4.0		0.9	5.2	5.7	10.6	31.7	103.3	161.3
DEEP-RIP-RP	729		7.3		4.6	3.9	10.5	43.0	72.9	142.2
PLOUGH/CULTIV-RP	976	5.0		1.8	6.6	6.6	11.3	22.3	97.6	151.3
SP-WIDE ROW-RP	522			1.0	7.3	3.7	9.3	20.7	52.2	94.0
DP-SKIP ROW-RP	798	4.5		1.8	5.0	4.0	7.0	21.0	79.8	123.6

1. Totals and averages may not be exact due to rounding.

TABLE 4: AVERAGE RETURNS PER HECTARE AND RETURNS TO LABOUR, IN PULA, NATIONAL TILLAGE TRIAL, FRANCISTOWN AREA, 1988-1989

REP	YIELD KG/HA	TOTAL LABOUR HOURS	GTVP PULA[a]	COSTS PULA[b]	NTVP PULA[c]	RETURNS TO LABOUR GROSS PER HR	RETURNS TO LABOUR NET PER HR
			--- PER ONE HECTARE ---				
SINGLE PLOUGH-RP	810	128.4	364.28	165.50	198.78	2.84	1.55
DOUBLE PLOUGH-RP	1033	161.3	464.76	215.50	249.26	2.88	1.55
DEEP-RIP-RP	729	142.2	328.17	215.50	112.67	2.31	0.79
PLOUGH/CULTIV-RP	976	151.3	439.27	215.50	223.77	2.90	1.48
SP-WIDE ROW-RP	522	94.0	234.78	165.50	69.28	2.50	0.74
DP-SKIP ROW-RP	798	123.6	359.03	215.50	143.53	2.90	1.16

a. GTVP = Gross Total Value Product (yield x price) where price = P0.45/kg.
b. COSTS = Tractor rental = P50.00/ha, fertilizer cost -- 4 bags @ P28.00/bag = P112.00, estimated seed cost -- 4kg/ha x P0.50/kg = P2.00/ha., and estimated equipment repair = P1.50/ha.
c. NTVP = Net Total Value Product (GTVP - COSTS).

CONCLUSIONS

This experiment was part of a set of experiments nationwide. Specific conclusions regarding treatment effects cannot be drawn from this one location, in one year. More so, since there were no statistical differences detected

between treatments. Specific conclusions should await a combined analysis of the complete data set over all eight locations.

However, some specific recommendations can be made regarding the conduct of this trial in the coming year. These are as follows:

(a). A careful analysis should be made of the soil data, by plot, in this trial to determine whether there is a gradient across the experiment in terms of soil moisture holding capacity, soil texture and/or soil fertility. Variations in soil fertility could be corrected by applying varying amounts of fertilizer (by plot) in the coming season.

(b). Plant stand densities will need to be more closely controlled to avoid confounding effects.

(c). The proper equipment for implementing treatments will need to be on-site well before implementation begins in order to avoid the problems that occurred this year.

(d). Adding a third replication might be necessary to improve local precision, though this might complicate the logistics of trial implementation considerably.

APPENDIX 1

DAILY RAINFALL AMOUNTS AT THE NATIONAL TILLAGE TRIAL SITE, LOCATION 1, FRANCISTOWN REGION, 1988-1989

DAY	MONTH: SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
	MOUNT OF RAINFALL (MM)								
1									
2									
3					24				
4									
5					3				
6									
7				10					
8				4					
9									
10									
11				6					
12		2				15			
13									
14				9					
15				1					
16							7		
17									
18									
19						20			
20		9				36			
21		16				10			
22		14						30	
23					7	71			
24						70			
25						5			
26				30				21	
27					11				
28		12							
29									
30									
31									
TOTAL (MM)	0	53	0	60	45	227	7	51	0

TOTAL RAINFALL = 437

APPENDIX 2

HARVEST DATA COLLECTION INSTRUCTIONS, NATIONAL TILLAGE TRIALS (ALL LOCATIONS), 1988-89

1. On day of harvest, record plot number and harvest assessment date on Data Sheet of each plot harvested. One sheet will be used for each plot.

2. In the unfortunate situation where the host farmer has already partially harvested plots, take a sample of thirty heads from the threshing floor that were harvested from the trial area. The average weight of these heads will be used to estimate the grain already harvested from stalks that show harvest cutting.

3. Sub-sample each plot in the trial with a 2m x 2m quadrat. Take twenty quadrat sub-samples in a systematic pattern from each plot. The sub-sampling pattern is described below.

4. Three people should work with each quadrat sampling. Two will carry the rigid quadrat. When locating sub-sample positions in the plot, the front quadrat carrier directs the movement along the correct sampling line. The rear quadrat carrier counts paces and stops the movement at each sub-sample position. To avoid bias, this rear carrier should walk somewhat blindly. When he stops at a sub-sample position, the quadrat should be gently lowered and placed immediately in front of his toe. The third person records data and carriers sample bags and the plant height measurement stick. Quadrat carriers assist in making counts and harvesting heads.

5. Field assessments are made and recorded for total number of sorghum plants alive within the quadrat, number of these plants that have produced grain, and average plant height. Average plant height is for productive plants in the quadrat only and is based on visual gauging of average height to base of main panicles.

6. All sorghum heads or signs of sorghum heads within the quadrat are counted. These are recorded as follows:

   HR - Heads which were harvested by farmer before this sampling date. Signs of cutting will be evident on each stalk.

   MT - Heads which are present and ready for harvest.

   GR - Heads which are still immature but which, in the jugement of the researcher, could still be harvested at a later date. GR heads are more likely to be a factor in broadcast plots which tend to have a wider range of maturity.

   GZ - Heads which are missing and stalk or panicle shows signs of feeding by livestock. Partially damaged heads will be treated as MT heads.

7. All MT heads are cut and put in large brown paper kraft bags. Usually #12(?) bags (or larger) are adequate to hold all heads from a single quadrat sub-sample. Labeling on bags should include field designation, plot and quadrat number. A good procedure is to label all bags for a single plot just before beginning sampling that plot. Too many labeled bags causes confusion in sorting in the field. Labeling at each sub-sampling takes more time. Sample bags should be folded shut and stapled to prevent heads from falling out.

8. Sample bags from a single plot can be packed together in a large burlap bag for transporting.

9. Head samples can be oven dried in the paper bag. When sun drying, heads must be removed from the bag. A large protected space is required for sun drying samples.

10. When head samples are at a uniform threshing moisture, heads per quadrat sub-sample are counted, threshed and the grain weighed. Data are recorded on the harvest data sheet. The labeled paper bag is used to hold the grain sample through the weighing step.

11. Grain per quadrat is calculated as follows:

    Avg. weight (gm) of threshed sample heads x MT head count
    + Avg. weight (gm) of T.Floor sample x HR head count
    + Avg. weight (gm) of threshed sample heads x GZ head count

    GR head production can be factored in by adding an estimate of average GR head weight x GR head count. The estimate of average GR head weight could be that of the MT heads sampled or the average of additional sampling later in the season. GR head production is not usually an important factor in trials where researchers control the timing of harvest.

NATIONAL TILLAGE TRIAL

FORM 11

HARVEST ASSESSMENTS ON PLANT STAND, PRODUCTIVE PLANT NUMBER, GRAIN HEAD WEIGHT AND GRAIN YIELD

VILLAGE: _____ *VILL* _____

FARMER NAME: _____ *NAME* _____

PLOT NUMBER: _____ *PLOT* _____

HARVEST ASSESSMENT DATE: _____ *HVDA* _____

COMPLETE THRESHING DATE: _____ *CTDA* _____

THRESHING FLOOR SAMPLE (USE ONLY IF NEEDED): NOS. HEADS (*TENH*): _____

TOTAL WEIGHT (*TEHW*): _____ AVG. WEIGHT (*TEAW*): _____

Quadrat No.	FIELD ASSESSMENTS: Total No. SG	# Prod SG	Plant Ht (cm)	SG Head Numbers: HB	MT	GB	GZ	THRESHING DATA: Field Samples: NO.	GM.	Average	T Floor Average	Grain (Grams)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
Total												
Average												
Codes *	TNPT	PNPT	PTHT	HB	MT	GB	GZ	GMHN	GMWT	HAV	THAV	SMG*

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APPENDIX 3

PLOT MAP FOR NATIONAL TILLAGE TRIAL,
LOCATION 1, FRANCISTOWN REGION, 1988-1989

PLOT No.:	206	205	204
TREATMENT:	5	4	3
GRAIN YIELD:	405	1289	917
PLOT No.:	201	202	203
TREATMENT:	6	1	2
GRAIN YIELD:	745	791	1066
PLOT No.:	106	105	104
TREATMENT:	1	3	2
GRAIN YIELD:	829	541	1000
PLOT No.:	101	102	1[illegible]
TREATMENT:	5	4	6
GRAIN YIELD:	639	663	851

NORTH
W — E
S

Treatments: 1 = Conventional; 2 = Double plough;
3 = Deep-rip; 4 = Plough/cultivate;
5 = Conventional plus wide rows;
6 = Skip row planting (double ploughed).

File: P300.1/PR F90-4 - 13 - July 4, 1990

APPENDIX 4

LABOUR TIMES, PERSON HOURS PER HECTARE, NATIONAL TILLAGE TRIAL, FRANCISTOWN AREA, 1988-1989 [a]

	REP	YIELD KG/HA	FIRST PLOUGH	DEEP-RIPPING	FERT	PLOUGH	ROW PLANT	THIN	WEEDING	HARVEST THRESH	TOTAL TIME
					SINGLE PLOUGH-ROW PLANT						
	1	829			1.0	3.5	5.8	12.0	21.7	82.9	128.9
	2	791			0.8	4.3	6.2	11.8	25.7	79.1	127.9
AVG		810			1.9	3.9	6.0	11.9	23.7	81.0	128.4
					DOUBLE PLOUGH-ROW PLANT						
	1	1000	4.0		0.8	3.2	4.5	9.7	31.0	100.0	153.2
	2	1068	4.0		1.0	7.2	6.8	11.5	32.3	106.8	169.4
AVG		1033	4.0		0.9	5.2	5.7	10.6	31.7	103.3	161.3
					DEEP-RIP-ROW PLANT						
	1	541		7.5		5.2	4.0	13.8	57.3	54.1	142.0
	2	917		7.0		4.0	3.8	7.2	28.7	91.7	142.4
AVG		729		7.3		4.6	3.9	10.5	43.0	72.9	142.2
					PLOUGH/CULTIVATE-ROW PLANT						
	1	883	5.0		2.2	5.7	6.3	11.2	23.3	88.3	120.0
	2	1289	5.0		1.5	[illegible]	6.8	11.5	21.3	128.9	182.8
AVG		976	5.0		1.8		6.6	11.3	22.3	97.6	151.3
					SINGLE PLOUGH-WIDE-ROW PLANT						
	1	639			1.2	8.2	2.8	12.0	16.0	63.9	104.0
	2	405			0.8	6.3	4.5	6.5	25.3	40.5	84.0
AVG		522			1.0	7.3	3.7	9.3	20.7	52.2	94.0
					DOUBLE PLOUGH-SKIP ROW-ROW PLANT						
	1	851	4.0		1.9	6.0	4.0	8.5	22.3	85.1	131.7
	2	745	5.0		1.7	4.0	4.0	6.7	19.7	74.5	115.5
AVG		798	4.5		1.8	5.0	4.0	7.6	21.0	79.8	123.6

a. Totals and averages may not be exact due to rounding.

APPENDIX 5

RETURNS PER HECTARE AND RETURNS TO LABOUR, IN PULA, NATIONAL TILLAGE TRIAL, FRANCISTOWN AREA, 1988-1989

	REP	YIELD KG/HA	TOTAL LABOUR HOURS	GTVP PULA[a]	COSTS PULA[b]	NTVP PULA[c]	RETURNS TO LABOUR GROSS PER HR	RETURNS TO LABOUR NET PER HR
				--- PER ONE HECTARE ---				
				SINGLE PLOUGH-ROW PLANT				
	1	829	128.9	372.83	165.50	207.33	2.89	1.61
	2	791	127.9	355.73	165.50	190.23	2.78	1.49
AVG		810	128.4	364.28	165.50	198.78	2.84	1.55
				DOUBLE PLOUGH-ROW PLANT				
	1	1000	153.2	449.96	215.50	234.46	2.94	1.53
	2	1068	169.4	479.57	215.50	264.07	2.83	1.56
AVG		1033	161.3	464.76	215.50	249.26	2.88	1.55
				DEEP-RIP-ROW PLANT				
	1	541	142.0	243.63	215.50	28.13	1.72	0.20
	2	917	142.4	412.72	215.50	197.22	2.90	1.39
AVG		729	142.2	328.17	215.50	112.67	2.31	0.79
				PLOUGH/CULTIVATE-ROW PLANT				
	1	[illegible]	120.0	298.53	215.50	83.03	2.49	0.69
	2	[illegible]	182.6	580.00	215.50	364.50	3.18	2.00
AVG		976	151.3	439.27	215.50	223.77	2.90	1.48
				SINGLE PLOUGH-WIDE ROW-ROW PLANT				
	1	639	104.0	287.41	165.50	121.91	2.76	1.17
	2	405	84.0	182.14	165.50	16.64	2.17	0.20
AVG		522	94.0	234.78	165.50	69.28	2.50	0.74
				DOUBLE PLOUGH-SKIP ROW-ROW PLANT				
	1	851	131.7	382.77	215.50	167.27	2.91	1.27
	2	745	115.5	335.30	215.50	119.80	2.90	1.04
AVG		798	123.6	359.03	215.50	143.53	2.90	1.16

a. GTVP = Gross Total Value Product (yield x price) where price = P0.45/kg.
b. COSTS = Tractor rental = P50.00/ha, fertilizer cost -- 4 bags @ P28.00/bag = P112.00, estimated seed cost -- 4kg/ha x P0.50/kg = P2.00/ha., and estimated equipment repair = P1.50/ha.
c. NTVP = Net Total Value Product (GTVP - COSTS).