PROJECT R8197 [FTR Part 3]
APPENDIX 2. ON-FARM VALIDATION OF COTTON ICM COMPONENTS
[On-farm trials conducted in Teso with SAARI]

Report 1:

Evaluation of cotton management practices 2003

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Based on statistical analysis by G M Arnold

February, 2004

Summary

On-farm trials to compare two cotton cropping systems (pure cotton or a cotton-bean inter-crop), two fertiliser regimes (- or + fertiliser) and two tillage practices (minimum tillage with herbicide or conventional ploughing) were undertaken in six districts of north-eastern Uganda. Significant yield increases were associated with sole crop cotton and use of fertiliser. Tillage practice had no significant effect on cotton yield or subsequent in-crop weed populations. Fertilise use was uneconomic at the majority of sites, and up to a selling price of UG Sh. 500 per kg the additional bean harvest did not cover the loss in cotton yield observed under the inter-cropping system.Introduction

The APEP (previously IDEA and SPEED) project is running a programme of demonstrations of an improved, high input, approach to cotton production in major cotton growing areas of Uganda. The package is demonstrated as a whole and includes use of reduced tillage with application of the herbicide glyphosate (Roundup) prior to planting, in order to reduce labour and draught inputs for land preparation, and use of fertiliser. Serere Agricultural Research Institute in collaboration with NRI is undertaking a study of component cotton production practices in a series of on-farm trials in a number of districts of north-eastern Uganda. Farmers may well choose to adopt components of the production package that they believe are best suited to their resources. The aim of this study is therefore to understand the possible contribution of fertiliser use, cropping pattern and weed management options to cotton productivity. Trials were undertaken during 2003 and will be continued during 2004.

An overview of the 2003 trials, with site descriptions, detailed methods, raw data and a preliminary analysis has been reported by staff at Serere[1]. Further detailed statistical analysis of the data is reported here.

Methods

Trials were planted at 20 on-farm sites in early May 2003 but due to subsequent insecurity it was not possible to maintain regular visits to all sites. This and other problems with plot location or missing data reduced the number of sites for which adequate data sets were available for analysis to 14. Weed data was however collected at 20 sites early in the season.

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[1] P. Elobu, T.J. Takon and O. Solomon (2003) Annual report for IPM smallholder cotton project at Serere Research Institute for 2003. Soroti, Uganda: SARI.

Treatments and data collection

Eight plots were established at each location as follows:

1. Minimum tillage/herbicide use, pure cotton, no fertiliser
2. Minimum tillage/herbicide use, pure cotton, fertiliser applied
3. Minimum tillage/herbicide use, cotton inter-crop with beans, no fertiliser
4. Minimum tillage/herbicide use, cotton inter-crop with beans, fertiliser applied
5. Conventional tillage, pure cotton, no fertiliser
6. Conventional tillage, pure cotton, fertiliser used
7. Conventional tillage, cotton inter-crop with beans, no fertiliser
8. Conventional tillage, cotton inter-crop with beans, fertiliser used

Minimum tillage plots were generally ploughed once 10 to 15 days prior to planting. Weed re-growth was then sprayed with the herbicide Touchdown (sulfusate), applied at rate of 180 mls per 15 l water, at planting. The effects of Touchdown are generally reported to be similar to those of Roundup (glyphosaate). At two of the sites included in the subsequent analysis herbicide treated plots were no-till. Here, herbicide was applied twice with no land preparation. Examination of the yield data did not suggest this practice had a differential effect to the minimum tillage system so these sites were included with other farms in the analysis.

All fertiliser (NPK) was applied at planting at a dose of 200 kg ha^{-1}. Cotton (BPA 97) was planted at a spacing of 75 x 30 cm. Beans, on inter-crop plots, were sown in cotton inter-rows at 70 x 30cm. Both crops were thinned to two plants per planting station.

Numbers of major weed species were recorded from four random quadrats (0.5 x 0.5 m) in both minimum tillage and conventional tillage bocks prior to first (20-25 days after planting , DAP) and second (± 60 DAP) weeding. Pest control at all sites was by up to three applications of Contra-Z with first spraying delayed until after 70 DAP to allow build-up of natural enemies. Routine monitoring of pest populations at the trial sites was not undertaken due to insecurity in the region. Similarly no data on diseases or nematode attack is available for use in the analysis. Soil chemical and physical analysis was undertaken for all sites.

Results

For analysis each site was assumed to comprise a complete block of the 8 treatment combinations. Within each site, the 8 plots were split into two 'main' plots on which two crop systems were compared (pure cotton, cotton/bean inter-crop) and, within these 'main' plots, fertiliser use (-/+ fertiliser) * tillage system (herbicide, conventional) were compared on the four 'sub'-plots. For some of the measured variables data were missing from complete sites so these sites have been excluded from the analysis. As all main effects and interactions for the 2^3 treatment structure have a single degree of freedom in the Analysis of Variance (ANOVA), no further t-tests were required as they are exactly equivalent to the variance ratio F test. Data were examined for compliance with assumptions of the ANOVA procedure and necessary transformations were undertaken where necessary and indicated below.

<u>Crop responses</u>

Cotton height: This was assessed prior to harvest as an indicator of crop vigour and data was available from 10 sites for analysis.

Crop system overall ($p=0.005$), and fertiliser ($p=0.049$) had significant effects on cotton height, but no other effects or interactions were significant. Cotton grew taller in pure stand where there was no competition from a bean inter-crop and where fertiliser had been applied:

Crop system	Pure cotton	Cotton/bean inter-crop	
Mean	94.0	83.4	SED(9df) = 2.82

Fertiliser use	None	+Fert	
Mean	85.0	92.4	SED(54df) = 3.72

Cotton yield: Data were available from 14 sites. Once again no data transformation was required. The results were similar to those for height, with only the main effects for crop system ($p=0.006$) and for fertiliser use ($p<0.001$) being significant. Yields harvested from sole crop cotton were 25% greater than from the inter-crop, fertiliser increased yield by 18% on average:

Crop system	Pure cotton	Cotton/bean inter-crop	
Mean	1089	870	SED(13df) = 67.5

Fertiliser use	None	+Fert	
Mean	899	1059	SED(78df) = 40.1

Bean yield: Data on bean yield were available for 13 sites. Yields were generally low, ranging from 80 to 570 kg ha^{-1}, with mean yield depressed by crop failure at two sites due to wilt disease early in the season. To improve the variance homogeneity a log transformation was required; an increment of 20 was added to each yield before taking logs in order to include the zero yields in the analysis. Only the plots in the intercrop system had beans planted, thus the analysis is based on 52 plots in total (one of which was a true missing value). The overall fertiliser effect was significant ($p=0.007$) with 16% higher bean yields harvested from fertilised plots:

Fertiliser use	None	+Fert	
Mean [$\log_e$(yield+20)]	4.874	5.006	SED(35df) = 0.0671
Back-transf. Mean kg ha^{-1}	110.8	129.3	

Income: The productivity of sole or inter-cropping can be compared by reference to the monetary value of the harvest. This was assessed by assuming a cotton farm gate price of UG Sh. 500 Kg^{-1} and two prices for beans, either Sh. 300 or Sh. 500 kg^{-1} reflecting different values for the commodity at different times of the year.

At a bean selling price of Sh. 300 only the main effect of fertiliser use is significant ($p<0.001$) such that there was a higher overall income where fertiliser was applied. The effect of crop system had a probability level just below 0.1 ($p=0.096$):

Fertiliser use	None	+Fert	
Mean	482374	561161	SED(71df) = 21695

Crop system	Pure cotton	Cotton/bean inter-crop	
Mean	551123	492411	SED(12df) = 32540

The relative performance of the systems remained the same when the bean price was increased to Sh. 500. with fertiliser use significantly ($p<0.001$) increasing income by 16%.

Fertiliser use	None	+Fert	
Mean	500620	582726	SED(71df) = 22292

Effects of soil fertility: Soil data from 13 sites comprised a site reading for each of pH, % organic matter, % nitrogen, phosphorous, potash, calcium and % sand. Cotton yields were extracted for the two plots growing pure stand cotton with no added fertiliser. An initial ANOVA of these 26 cotton yield values gave no indication of any effects due to the differing tillage regimes on the two plots within sites. Overall there was evidence of site to site variability (p=0.005). An initial regression analysis ignored the structure of plots within sites and treated units as 26 separate units. Individually the only soil record giving a significant linear regression for cotton yield was phosphorous (p=0.003, a positive coefficient indicating increasing yield with increasing levels of phosphorous). A multiple regression was then carried out and both methods (forward selection and backward elimination) selected the same 3 soil explanatory variables; these were phosphorous, % sand and calcium.

However, when the structure of the units was taken into account (i.e. 2 yield values for each site and therefore its single measurements for the soil variables), the residual MS on 22 degrees of freedom could be partitioned into lack-of-fit (on 9 df) and within site residual (on 13 df). The lack-of-fit was significant (F =2.979 on 9 & 13 df, p=0.036) and testing the overall regression against lack-of-fit was then not quite significant (F=3.215 on 3 & 9 df, p=0.083). Thus this regression appears to be of only borderline significance. In the table below the parameter estimates are given along with the two estimates of standard error (from lack-of-fit on 9 df and from combined residual on 22 df) and their corresponding individual significance.

Parameter	Estimate	SE (on 9 df)	t-prob	SE (on 22 df)	t-prob
Constant	1766	468	0.001 ***	808	0.057 (*)
Phosphorous	13.28	4.16	0.004 **	7.18	0.097 (*)
% sand	–9.60	4.70	0.054 (*)	8.11	0.267
Calcium	–4.28	3.35	0.214	5.78	0.478

From the table above it can be seen that, even ignoring structure, only Phosphorous and % sand were significant at around p=0.05 (Phosphorous rather more so, % sand very borderline). The data suggest that yields are higher from soils with greater phosphorus content and there is a slight indication that they are lower on free-draining soils with a high sand content.

Treatment effects on weeds: In all cases the distribution of weed counts showed strongly increasing variance with increasing mean. The use of a log transformation [$\log_e$(count+1)] was reasonably successful throughout in giving a more uniform spread of residuals. In addition to examining treatment effects on total weed number three important species, the rhizomatous grass *Imperata cylindrica*, perennial *Cyperous* spp. and *Commelina benghalensis* were considered separately. These are difficult to control by mechanical means and observations after spraying suggested that *Commelina* was poorly controlled by the herbicidde. However, for none of the analyses undertaken was there any evidence of any significant effects of tillage on counts. Also, the ordering of the two means differed for different counts, with some showing conventional having more weeds and some showing the reverse (although none of these differences was statistically significant). Below are the means for each count (on the log scale and back transformed scale) for the two different forms of tillage.

Weed populations prior to first weeding (No. m^{-2} from back transformed data)

	Conventional tillage		Minimum tillage		
Weed	Log	No. m^{-2}	Log	No. m^{-2}	SED(19df)
Imperata	0.82	1.27	0.78	1.19	0.170
Cyperus	1.60	3.95	1.52	3.57	0.263
Commelina	1.92	5.82	2.04	6.69	0.220
Total Perennials	2.76	14.8	2.62	12.7	0.221
Total annuals	4.17	63.5	4.27	70.5	0.195
Total weeds	4.45	84.4	4.55	93.5	0.168

Weed populations prior to second weeding (No. m^{-2} from back transformed data)

	Conventional tillage		Minimum tillage		
Weed	Log	No. m^{-2}	Log	No. m^{-2}	SED(19df)
Cyperus	1.5	3.48	2.04	6.69	0400
Commelina	1.75	4.75	1.45	3.26	0.322
Total Perennials	2.61	12.6	2.59	12.2	0.383
Total annuals	3.66	37.9	4.03	55.3	0.294
Total weeds	4.04	55.8	4.37	78.0	0.232

Discussion

Yields of fertilised cotton ranged from 733 to 2200 kg ha^{-1} with seven sites producing 1000 kg ha^{-1} or less. These yields were somewhat less than those achieved by farmers participating in IDEA/SPEED cotton production demonstrations in Palisa during the previous season[2]. An average 2288 kg ha^{-1} seed cotton was harvested from areas managed according to the high input package in the demonstrations including pre-plant application of herbicide and use of fertiliser. In 2003, at a cotton farm gate price of UG. Sh. 500 per kg, an additional 280 kg ha^{-1} seed cotton would have been needed to cover the cost of the fertiliser. While fertiliser significantly boosted cotton yields in the current trials the additional harvest only covered the cost of the fertiliser or led to a profit at three of the 14 sites for which full data sets are available. In the 2002 season fertiliser use was reported to result in an average yield increase of 1027 kg ha^{-1} in the Palisa area. The reason for the difference in yield levels is not known but may be related to weather conditions.

There was no evidence in the trials for any effect on yield of the change from the conventional practice of ploughing twice to a reduced tillage system incorporating the use of a herbicide. The major advantage for the farmer is that saving in and labour, draught at land preparation. For those who need to hire a draught team there is an added advantage of being able to plant when weather conditions are optimum as there is no need to wait for draught to become available to undertake a second plough pass. Farmers participating in the demonstration programme have reported that subsequent weeding is easier after using herbicide and that less labour is needed compared to weeding following conventional tillage. Weed data collected

[2] Impact Analysis of Enterprise-Linked Extension Program: Nyakatonzi Growers Cooperative Union and North Bukedi Cotton Company. Chemonics International (2003)

from the trials did not provide any evidence to show that in-crop weed populations were lower after herbicide application. This aspect needs more detailed investigation in 2004. A detailed economic analysis of costs and benefits of herbicide application is also needed. However, in 2003 no data was collected on labour use for weeding.

Bean inter-crops were clearly detrimental to cotton growth in the trials and up to a selling price of Sh. 500 per kg the additional bean harvest did not offset the reduction in seed cotton yield. Beans also proved to be a risky crop with generally low yields and crop failure due to disease at some sites.

Considerations for 2004

- Reconsider fertiliser management. Is the optimum formulation, dose and time of application being made. Ensure fertiliser use is same as that used in APEP demonstrations;
- Ensure adequate weed monitoring. In addition to weed counts make assessments of % cover;
- Interview farmers to assess labour use for weeding as effected by herbicide use;
- Collect data on pest and disease levels in cotton to use as collateral data in the yield analysis to further explain yield patterns;
- Ensure rain gauges are installed prior to planting at all sites.

Summary of SAARI OFTs 2003 showing soil analysis for each site and seed cotton yields from fertilised and non-fertilised plots of sole-crop cotton.

Farmer	Rain guage	Rainfall		pH	OM	N	Texture	Mean yield		
		M/J	Tot					+ Fert	-Fert	Diff.
Etoori, S.	Kalaki	-		5.9	4.4	0.15	SL	1800	1150	+650
Opinya, P.	Katine	-		6.0	2.3	0.10	LS	2200	1817	+383
Inangolet, P.	Katakwi	-		6.0	2.2	0.13	LS	1110	734	+376
Oligo, W.	Obulubulu	230		5.5	4.3	0.17	SL	1677	1330	+347
Okodan, A.	Kanyum	187		6.0	1.6	0.10	LS	1234	983	+251
Mugoda, M	Kibuku	166		5.5	3.2	0.18	SCL	1672	1467	+205
Oluka, P.	Kyere	-		5.1	2.5	0.10	SL	900	700	+200
Abuko, V.	Kapujan	145		5.5	1.0	0.07	LS	534	367	+167
Edon, F.	Kamuda	273		5.2	2.0	0.08	SL	1400	1334	+66
Polot, A.	Mukura	116		5.6	1.7	0.08	LS	734	700	+34
Bosco, J.	Ongiino	352		5.6	1.3	0.05	LS	1000	1000	0
Otiti, Y	Alwa	183		5.9	3.7	0.15	SCL	735	900	-265
Ojulong, P.	Kapir	187		6.0	1.5	0.10	LS	967	1467	-500
MEAN [All]								1177	1073	[10%]
MEAN [Best 8]								1391	1069	[30%

Report 2:

Evaluation of cotton management practices 2004

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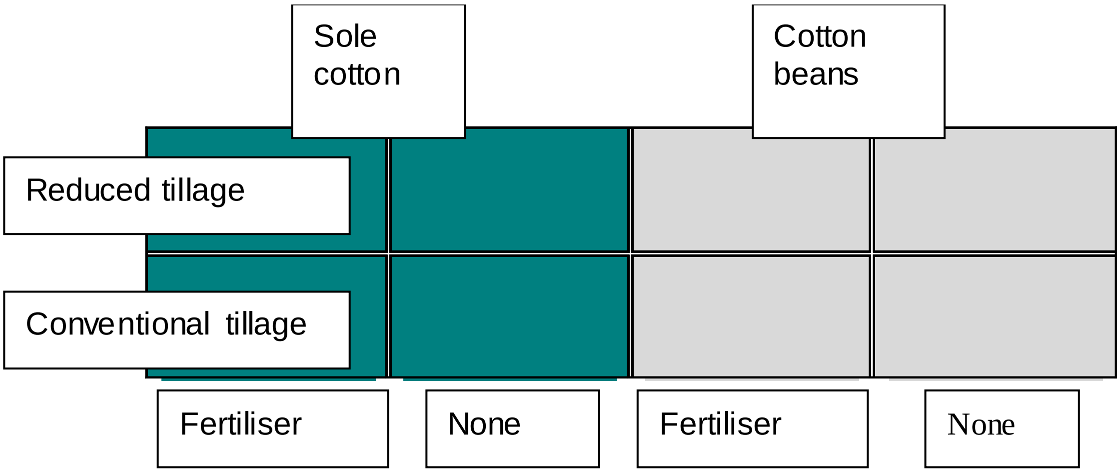
Based on statistical analysis by G M Arnold

February, 2005

Introduction

The APEP cotton production package being demonstrated to farmers includes establishing the crop following reduced tillage and a pre-plant application of herbicide, fertiliser and IPM. To evaluate the profitability of the reduced tillage and fertiliser components on-farm trials were established at 27 sites in Pallisa, Kumi and Soroti districts during the 2004 season. Farmers undertook tillage and planting with their own draft power and labour. The project laid out the plots and provided training and assistance with herbicide application and IPM. Eight plots were established at each site as shown below.



This allowed evaluation of cropping system, land preparation and fertiliser practices as follows:

Cropping system - sole cotton 30 x 75 cm (BPA 2000 in Pallisa and BPA 99 in Kumi and Soroti v cotton/bean intercrop (beans local white at 30 x 75 cm in cotton inter-rows);
Land preparation - Conventional tillage i.e. plough twice with animal drawn plough at two week interval with second pass the day of before planting v Reduced tillage i.e. plough once two weeks before planting followed by application of glyphosate (as the product Touchdown average dose 4.7 l ha^{-1}) on day of planting;
Fertiliser - applied (basal dose of one soda cap DAP per planting station, equivalent to 125 kg ha^{-1} with top dressing of 125 kg ha^{-1} urea at flowering v none.

In order to remove pest pressure as a factor, pesticides were applied as indicated by scouting, using thresholds developed by the project.

For analysis each site was assumed to comprise a complete block of the 8 treatment combinations. Within each site, the 8 plots were split into two 'main' plots on which two crop systems were compared (pure cotton, cotton/bean inter-crop) and, within these 'main' plots, fertiliser use (-/+ fertiliser) * tillage system (herbicide, conventional) were compared on the four 'sub'-plots. Data were examined for compliance with assumptions of the ANOVA procedure and necessary transformations were undertaken where necessary and indicated below. A full set of weed and crop stand data was available from all farms. Only 21 farms were included in the yield analysis, other sites with uneven plots or problems during trial implementation were excluded.

Results

Effect of tillage method and fertiliser use on crop stand: Both fertiliser use and method of land preparation had a highly significant effect ($p \leq 0.001$) on cotton emergence (Table 1). Overall, reduced tillage improved crop establishment compared to ploughing twice, particularly noticeable in unfertilized plots. Sowing was undertaken in to drying seedbeds with a long dry spell following planting at a number of sites. Under these conditions it is likely that seed bed moisture was more favorable for early seedling growth where there had been less soil disturbance with reduced tillage. The addition of fertiliser substantially decreased cotton stands. This effect was particularly visible on red, free draining sandy soils that were low in organic matter. It is possible that fertiliser placed near to the seed attracted moisture so reducing water available to the germinating seedling. The damaging effect of fertiliser resulted in farmers carrying out gap filling with fresh seed but this was largely unsuccessful and increased stand to only 62% of hills on fertilized plots, significantly less than on areas where basal fetiliser had not been applied ($p<0.001$).

Table 1: Effect of land preparation practice and application of 125 kg ha^{-1} DAP at planting on cotton stand establishment. Data angular on angular scale with actual values of the % hills planted with at least one emerged cotton plant shown in brackets.

	Fertiliser	
Land preparation	**None**	**+ Fertiliser**
Reduced	70.5 (89%)	49.5 (58%)
Conventional	60.3 (61%)	47.3 (54%)
SED fert within till (100 df)	1.7	
SED between till (95 df)	1.6	

Effect of herbicide on weed infestation: Overall the % ground covered by weeds at first weeding was significant higher ($p<0.001$) on plots planted following conventional tillage than where reduced tillage and herbicide had been used (Table 2). However there was also some indication of differences in that effect between districts (significant tillage x district interaction, $p=0.016$). Herbicide significantly reduced subsequent weed cover across farms in Pallisa and Kumi. In Soroti, where weed cover on conventionally tilled plots was 18% and 60% of that in Pallisa and Kumi respectively, the difference between the two treatments was not large enough for individual significance. It also appears that the % weed cover scores in the Pallisa district are higher overall than from the other two districts. Of the problem perennial grasses and sedges in the areas where the trials were located *Cynodon dactylon* and *Digitaria abyssinica* were well controlled at the doses used while *Cyperus rotundus* and *Imperata cylindrica* were suppressed so that these did not compete with cotton seedlings. *Commelina benghalensis* formed dense stands at some locations but was not well controlled by glyphosate. Denser populations of these problem species were observed in Pallisa contributing to greater weed cover than found elsewhere.

Table 2: Effect of tillage method and herbicide use on weed growth prior to first weeding. Mean % weed cover on logit scale with back transformed means shown in brackets.

	District		
Land Preparation	**Pallisa**	**Kumi**	**Soroti**
Herbicide	-2.36 (8.6%)	-3.01 (4.7%)	-3.01 (4.7%)
No herbicide	-0.45 (38.9%)	-1.90 (11.9%)	-2.57 (7.1%)
SED (24 df)	0.333	0.244	0.333
t-probability	<0.001 ***	<0.001 ***	0.193 ns

Figure 1: Control of perennial grasses (*C. dactylon* and *D. abyssinica*).
Glyphosate was applied to right hand side of the area shown.

Bean yield: Bean plants were only established at 59 % of the hills that were planted in unfertilised cotton/bean intercrop plots (Table 3). Basal application of fertiliser to beans reduced emergence dramatically ($p<0.001$). Some attempts were made to re-plant but these were unsuccessful at many sites due to dry conditions after re-seeding. Beans were only harvested at 10 sites due to a combination of dry conditions and leaf diseases. Crops surviving to harvest produced extremely poor yields at a mean of 98 kg ha^{-1} + 11 on unfertilised plots and 170 kg ha^{-1} + 21 where fertiliser was applied to cotton.

Table 3: Bean crop stand two weeks after planting. Data on angular scale with actual values of the % hills planted with at least one emerged bean plant shown in brackets. Some attempts were made to re-plant but these were unsuccessful due to dry conditions after re-seeding.

Treatment	Bean stand
No basal fertiliser	50.3 (59%)
Fertiliser applied	32.2 (28%)
SED (50df)	2.23

Cotton growth and yield: The overall effect of fertilizer on cotton plant height (Table 4) was very large ($p<0.001$), but there was also strong indication of a crop system interaction with fertiliser ($p<0.001$). There was no evidence of land preparation practices effecting plant height. The increase in height for inter-cropped cotton when fertiliser was applied was 49.5, 48.2 cm in Pallisa and Kumi respectively. Fertiliser was applied at planting to beans at sites in these districts in error. compared to 30.1 In Soroti, where no fertilizer was applied to bean planting stations fertilizer application to cotton increased cotton height by 30.1 cm in the inter-crop, similar to the 26.8 cm increase in plant height in sole crop cotton. This could account for the crop system by fertiliser interaction described above. However on unfertilised plots competition from beans appears to have reduced cotton plant height, although as discussed below, bean populations were generally poor and the crop survived drought and disease to produce a yield at few sites.

Table 4: Effect of fertiliser and crop system on mean cotton height (cm) at harvest.

	Fertiliser	
Crop system	**None**	**+ Fertiliser**
Cotton	76.1	100.5
Cotton/beans	64.7	107.2
SED fert within crop sys. (107 df)	2.92	
SED crop within fert. (45 df)	3.32	

Fertiliser significantly increased seed cotton yield ($p<0.001$) (Table 5). Across all districts the mean yield of fertilised cotton was 1368 kg ha^{-1} ($\pm$ 46) compared to 939 ha^{-1} ($\pm$ 38) when unfertilised, an increase of 428 kg ha^{-1}. A district by fertiliser interaction (p=0.004) was evident. Yield also varied with crop system and tillage (p=0.023) (Table 6). With reduced tillage and herbicide use there appears to be no difference between cropping systems, but for conventional tillage the inter-crop has a significantly lower yield than cotton alone. For cotton alone conventional tillage gave a significant increase in yield compared to reduced tillage. The second ploughing of conventional tillage

Table 5: Seed cotton yields kg ha^{-1} in sole cotton and cotton/bean inter-crops as affected by fertiliser in Pallisa, Kumi and Soroti districts.

	Pallisa		**Kumi**		**Soroti**	
	Fertiliser					
Crop	**-**	**+**	**-**	**+**	**-**	**+**
Cotton	940	1141	1133	1347	945	1612
Coton/beans	793	1110	884	1470	845	1337

Table 6: Effect of land preparation and crop system on mean seed cotton yield kg ha^{-1}

	Tillage	
Crop system	**Reduced**	**Conventional**
Cotton	1119	1276
Cotton/beans	1125	1093
SED between crop sys. (32 df)	81.5	
SED till within crop sys (108 df)	57.9	

may have left a more open and uneven soil surface receptive to subsequent rain so improving soil water status for the benefit of developing crop, although this was not reflected in crop height. The overall mean increase in yield following fertilier application in Soroti of 609 kg ha^{-1} was somewhat larger than in Pallisa (258 kg ha^{-1}) and Kumi (399 kg ha^{-1}). However, looking at Table 5 this seems more to do with the increase in the yield of sole cotton rather than of inter-crop, suggesting that seed cotton yield increases were not caused by the extra basal fertiliser applied to beans in Pallisa and Kumi. The trend was for lower yield from cotton where it was inter-cropped with beans, suggesting competition from the inter-crop earlier in the season.

Soil and nutrients: As the soil characteristics are the same for all 8 plots within a farm, regressions were fitted for each treatment to explore the influence of various soil characteristics on seed cotton yield. When each soil variable was fitted separately, only organic matter content (OM) and potassium level (K) had any effect of significance. These were subsequently incorporated into a multiple regression. For neither explanatory variable (OM, K) was there any indication of an interaction with treatment, implying that the regression coefficient (‘slope’) could be deemed the same for each treatment (‘parallel lines’). The difference between treatments was adequately accounted for by different intercepts. The results were similar both for unfertilised plots and for all plots, so these are presented below with the standard errors and F-probabilities relevant for all data.

Explanatory variable	**F-prob (adjusted for the other expl. variable)**	**Coefficient (se)**
OM	0.004 **	-174.1 (59.7)
K	<0.001 ***	-1.147 (0.322)

Seed cotton yield appears to be negatively correlated with both organic matter and potassium content of soil with this relationship accounting for 34.6% of the total variation. This suggests that work with fertilizer formulations containing higher potassium content may be worthwhile.

Economic implications: Beans proved unreliable, failing to produce a harvestable yield at more than 50% of trial sites. Further more data has been presented indicating that bean inter-crops reduced cotton growth and yield. In on-farm trials conducted during 2003 beans were also found to be a risky crop, failing at 2 of 14 sites and producing a mean yield of 120 kg ha^{-1} (Riches, 2004). Competition was also significant with cotton. Indeed sole crop cotton produced 25% higher yield than the inter-crop with beans. Based on the evidence of these two seasons, beans are not a good option for inter-cropping in

Table 7: Costs and returns from use of tillage and cotton nutrient management options (**ha^{-1}**).

Treatment	**Reduced till/herbicide**		**Conventional tillage**	
	No fertiliser	**Fertiliser**	**No fertiliser**	**Fertiliser**
Costs that vary:				
Ploughing[1]	74,130	74,130	148,260	148,260
Herbicide[2]	65,940	65,940	-	-
Fetiliser[3]	-	112,500	-	112,500
Total costs that vary	140,070	252,570	148,260	260,760
Yield (kg)	917	1327	959	1408
Gross returns Sh.[4]	320,950	464,450	335,650	492,800
Net Returns	180,880	211,880	187,390	232,040

[1] Sh. 74,130 per ha per plough pass;
[2] Mean dose of Touchdown used in trials 4.7 L ha^{-1} costing Sh. 14,000 per L;
[3] Basal DAP 125 kg ha^{-1} with top dressing of 125 kg ha^{-1} urea
[4] Cotton price in 2004 buying season Sh. 350 per kg;

Table 7: Costs and returns from use of tillage and cotton nutrient management options.

	Reduced till/herbicide		**Conventional tillage**	
Costs/returns ha^{-1}	**No fertiliser**	**Fertiliser**	**No fertiliser**	**Fertiliser**
Yield kg	917	1327	959	1408

Income Sh.[1]	320,950	464,450	335,650	492,800
Ploughing[2]	74,130	74,130	148,260	148,260
Herbicide[3]	65,940	65,940	-	-
Fetiliser[4]	-	112,500	-	112,500
Total cost	140,070	252,570	148,260	260,760
Return	180,880	211,880	187,390	232,040

[1] Cotton price in 2004 buying season Sh. 350 per kg;
[2] Sh. 74,130 per ha per plough pass;
[3] Mean dose of Touchdown used in trials 4.7 L ha^{-1} costing Sh. 14,000 per L;
[4] Basal DAP 125 kg ha^{-1} with top dressing of 125 kg ha^{-1} urea

;

cotton. The combination of production practices that are therefore of interest from an economic point of view are those involving reduced land preparation with herbicide applied before planting and use of fertiliser. Partial budgets covering the variable costs of land preparation and fertiliser use options, computed from yields obtained from sole crop cotton, are shown in Table 7. At the relatively low cotton price (Sh. 350 kg ha^{-1}) for grade b cotton in 2004 buying season the most profitable option was to use conventional tillage and fertiliser. A number of caveats need to be added. Firstly, due to perennial weed infestations at a number of sites, the mean dose of herbicide used in the trials was high. Based on experience gained in 2003 higher doses wee used at sites with dense infestations of *C. rotundus, C. dactylon, D. abyssinica* or *I. cylindrica.* At sites with less sever infestations a lower dose could be used so reducing herbicide costs. Further more perennial weed infestations often have a “patch distribution” so that it will not be necessary to spray the entire field with a high dose. Glyphosate is also likely to reduce regrowth of the problem species leading over time to a reduction in infestation. However a long-term study would be needed to confirm that herbicide use and hence tillage costs can be reduced in subsequent seasons. Secondly, the budget shown assumes that farmers use the same amount of labour for in-crop weed control following both reduced and conventional tillage. Farmer observations from APEP demonstrations sites suggest that weeding times are reduced on land to which herbicide has been applied before planting. The weed cover scores reported here suggest that this is likely to be the case so increasing the profit from use of reduced tillage and reducing profit from cotton on areas that are ploughed twice due to greater expenditure on labour for weeding. Another advantage of using reduced tillage is that farmers who do not own draught power do not need to hire a team for a second ploughing. Competition for hire of draught could lead to later planting and this, depending on rainfall, may in turn result in lower yields.

Reference

Riches C.R. (2004) Evaluation of cotton management practices 2003. Chatham, UK: Natural Resources Institute.

<u>Appendices to 2003 SAARI on-farm trial report</u>

Details Of the 28 Locations Initially Selected For Demonstrations/Trials Of Small Holder Cotton IPM Project In 2003.

Farmer	Date selectd	District	Sub-county	Parish	Village
1. Okiror Joseph	10/3/2003	Katakwi	Abarilela	Katine	Akamuriei
2. Abuko Vicky	10/3/2003	Katakwi	Kapujan	Orimai	Osongai
3. Inangolet Peter	10/3/2003	Katakwi	Katakwi	Alukucok	Alukucok
4. Ojangole Charles	*10/3/2003*	*Katakwi*	*Weera*	*Weera*	*Aterai*
5. Ocen Enos	*11/3/2003*	*Katakwi*	*Morungatuny*	*Ogolai*	*Okao*
6. Akello Brenda	25/3/2003	Katakwi	*Toroma	Asuret	Orisai
7. Ocen-Olobo, J.P.	*12/3/2003*	*Kaberamaido*	*Kaberamaido*	*Kamuk*	*Goria*
8. Oligo Wilson	12/3/2003	Kaberamaido	Obulubulu	Abalkweru	Ogobai
9. Otiti Yokosafati	12/3/2003	Kaberamaido	Alwa	Palatau	Palatau
10. Ogwang Stansilas	*12/3/2003*	*Kaberamaido*	*Ochero*	*Anyalam*	*Alam*
11. Etoori-Elwoku Stanley	12/3/2003	Kaberamaido	Kalaki	Kalaki	Central
12.Opio Laurence	*12/3/2003*	*Lira*	*Kangai*	*Awelo*	*Owor*
13. Awio Lario	*11/3/2003*	*Lira*	*Amugu*	*Ajonyi*	*Teduka*
14. Opinya Patrick	12/3/2003	Soroti	Katine	Merok	Aputon
15. Edou Faustine	10/3/2003	Soroti	Kamuda	Aminit	Amotot
16. Ekellot Charles	*13/3/2003*	*Soroti*	*Gweri*	*Gweri*	*Amodama*
17. Opola John	*13/3/2003*	*Soroti*	*Arapai*	*Arapai*	*Arapai*
18. Oluka Peter	13/3/2003	Soroti	Kyere	Kangedo	Ojama Central
19. Ojakor John Bosco	11/3/2003	Kumi	Ongino	Ongino	Ongino
20. Opolot Alex	11/3/2003	Kumi	Mukura	Ajaluk	Adokar
21. Ojulong Papilio	11/3/2003	Kumi	Kapir	Omiiti	Omiito
22. Okodan Silver	11/3/2003	Kumi	Kanyum	Kamaca	Oput
23. Prisicilla Iculet Onyas	*12/3/2003*	*Pallisa*	*Apopong*	*Apopong*	*Okorotok*
24. Okanya Constant	*12/3/2003*	*Pallisa*	*Kibaale*	*Kapuai*	*Kapuai*
25. Opolot Peter	*22/3/2003*	*Pallisa*	*Kibaale*	*Kapuai*	*Kapuai*
26. Mugoda Mesulam	13/3/2003	Pallisa	Kibuku	Bumiza	Bumiza
27. Opolot Alex	*13/3/2003*	*Pallisa*	*Kamuge*	*Kamuge*	*Kamuge Station*

28. SAARI	-----	Soroti	Olio	------	(On-station)

Results Of Analysis Done To Soil Samples Before Planting Small Holder Cotton IPM Project Trials In 2003.

			Soil status in April 2003, before cropping for the season.										
Farmer	***District***	**Sub-county**	**PH**	**OM**	**N**	**P**	**K**	**Na**	**Ca**	**Sand**	**Clay**	**Silt**	**Textural class**
				….%….		***ppm***	***Mg/100 g of soil***			***……..%………***			
Okiror Joseph	*Katakwi*	*Abarilela*	*5.4*	*2.3*	*0.08*	*9.19*	*14.58*	*0.33*	*44.13*	*85.1*	*9.6*	*5.3*	*Loamy sand*
Abuko Vicky	Katakwi	Kapujan	5.5	1.0	0.07	3.60	9.17	0.89	20.17	89.1	5.6	5.3	Loamy sand
Inangolet Peter	Katakwi	Katakwi	6.0	2.2	0.13	8.79	26.25	0.67	76.91	87.1	7.6	5.3	Loamy sand
Ojangole Peter	**Katakwi**	*Weera*	*6.1*	*1.9*	*0.07*	*2.80*	*10.42*	*0.56*	*27.74*	*87.1*	*7.6*	*5.3*	*Loamy sand*
Ocen Enos	*Katakwi*	*Morungatuny*	*5.9*	*2.8*	*0.12*	*2.80*	*25.00*	*0.78*	*90.78*	*73.1*	*17.6*	*9.3*	*Sandy loam*
Akello Brenda	Katakwi	Toroma											
Ocen Olobo J.P.	*Kaberamaido*	*Kaberamaido*	*5.5*	*4.3*	*0.17*	*2.80*	*17.50*	*1.00*	*107.17*	*57.1*	*31.6*	*11.3*	*Sandy loam*
Oligo Wilson	Kaberamaido	Obulubulu	5.5	4.3	0.17	37.57	25.83	0.89	85.73	67.1	19.6	13.3	Sandy loam
Otiti Yokasafati	Kaberamaido	Alwa	5.9	3.7	0.15	9.59	29.58	0.67	104.65	63.1	25.6	11.3	Sandy clay laom
Ogwang stansila	*Kaberamaido*	*Ochero*	*5.8*	*5.3*	*0.18*	*48.95*	*36.67*	*0.44*	*162.57*	*63.1*	*25.6*	*11.3*	*Sandy clay loam*
Etoori-Elwoku S.	Kaberamaido	Kalaki	5.9	4.4	0.15	64.94	27.08	0.67	119.78	71.1	19.6	9.3	Sandy loam
Opio Laurence	*Lira*	*Kangai*	*5.2*	*4.5*	*0.22*	*5.20*	*27.92*	*0.33*	*115.99*	*53.1*	*31.6*	*15.3*	*Sandy clay loam*
Awio Lario	*Lira*	*Amugu*	*5.7*	*2.6*	*0.12*	*12.39*	*17.08*	*0.56*	*55.48*	*79.1*	*11.6*	*9.3*	*Sandy loam*
Opinya Patrick	Soroti	Katine	5.6	2.3	0.10	4.80	21.2	0.67	59.26	83.1	9.6	7.3	Loamy sand

							5						
Edou Faustine	Soroti	Kamuda	5.2	2.0	0.08	2.40	10.00	0.44	42.87	79.1	12.9	8.0	Sandy loam
Ekellot charles	*Soroti*	*Gweri*	*5.9*	*2.2*	*0.07*	*7.19*	*18.75*	*0.44*	*59.26*	*81.1*	*10.9*	*8.0*	*Loamy sand*
Opola John	*Soroti*	*Arapai*	*5.8*	*1.6*	*0.10*	*2.00*	*16.25*	*0.67*	*36.56*	*87.1*	*8.9*	*4.0*	*Loamy sand*
Oluka Peter	Soroti	Kyere	5.1	2.5	0.10	2.00	13.33	0.56	45.39	73.1	18.9	8.0	Sandy loam
Ojakor Jhn Bosco	*Kumi*	Ongino	5.6	1.3	0.05	6.80	15.00	0.22	47.91	87.1	5.6	7.3	Loamy sand
Polot Alex	Kumi	Mukura	5.6	1.9	0.08	17.59	13.75	0.33	59.26	85.1	9.6	5.3	Loamy sand
Ojuling Papilio	Kumi	Kapir	6.0	1.5	0.10	76.93	14.58	0.22	52.95	85.1	7.6	7.3	Loamy sand
Okodan Silver	Kumi	**Kanyum**	6.0	1.6	0.10	1.60	14.17	0.11	36.56	85.1	7.6	7.3	Loamy sand
Prisicilla Iculet	*Pallisa*	*Apopong*	*5.7*	*2.3*	*0.07*	*15.99*	*15.00*	*0.33*	*55.48*	*77.1*	*13.6*	*9.3*	*Sandy loam*
Okanya constant	*Pallisa*	*Kibaale*	*5.7*	*1.9*	*0.7*	*1.60*	*21.25*	*0.44*	*65.56*	*75.1*	*15.6*	*9.3*	*Sandy loam*
Opolot Peter	*Pallisa*	*Kibaale*											
Mugoda Mesulam	Pallisa	Kibuku	5.5	3.2	0.18	29.58	25.83	0.67	105.91	61.1	28.9	10.0	Sandy clay loam
Opolot Alex	*Pallisa*	*Kamuge*	*5.7*	*1.7*	*0.08*	*2.80*	*16.67*	*0.44*	*42.87*	*85.1*	*10.9*	*4.0*	*Loamy sand*
SAARI	Soroti	Olio	5.4	2.1	0.10	5.07	0.28	0.40	4.0	50.0	32.0	18.0	Silty clay loam

Numbers Of Different Weed Species Prevalent At The Various Locations Under Two Tillage Systems During Small Holder Ipm Cotton Project Trials In 2003

Sub-county	**First sampling before 1st - weeding**		**Second sampling before 2nd weeding**	
	Sprayed block	**Un-sprayed block**	**Sprayed block**	**Un-sprayed block**
Abarilela	9	14	-	-
Kapujan	7	7	-	-
Katakwi	13	9	-	-
Weera	8	9	-	-
Morungatuny	12	17	-	-
Toroma	9	13	-	-
Kaberamaido	16	18	22	19
Obulubulu	13	9	9	10
Alwa	14	17	19	12
Kalaki	8	13	10	16
Kangai	11	15	13	16
Amugu	7	9	-	-
Katine	12	11	16	6
Kamuda	16	13	-	-
Kyere	8	8	9	15
Ongiino	11	18	9	16
Mukura	11	8	15	21
Kapir	21	11	-	-
Kanyum	13	15	-	-
Apopong	23	16	21	16
Kibuku	13	8	16	12
SAARI	5	8	12	12
Mean	**12.1**	**12.1**	**14.2**	**14.2**

Total Weed Density Of The Different Weed Species Prevalent At The
Various Locations Under Two Tillage Systems During Small Holder Ipm Cotton Project Trials In 2003

	First sampling before 1st weeding		Second sampling before second weeding	
Sub-county	**Sprayed block**	**Un-sprayed block**	**Sprayed block**	**Un-sprayed block**
Abarilela	347	131	-	-
Kapujan	95	50	-	-
Katakwi	115	52	-	-
Weera	54	73	-	-
Morungatuny	89	133	-	-
Toroma	36	65	-	-
Kaberamaido	58	81	98	75
Obulubulu	25	17	15	22
Alwa	85	158	95	31
Kalaki	22	37	54	67
Kangai	134	50	97	90
Amugu	156	164	-	-
Katine	236	289	293	40
Kamuda	93	96	-	-
Kyere	19	67	33	54
Ongiino	457	241	264	169
Mukura	39	32	86	87
Kapir	353	55	62	173
Kanyum	230	498	18	156
Apopong	301	114	179	126
Kibuku	55	73	100	70
SAARI	20	21	71	37
Mean	**137.2**	**113.5**	**104.6**	**85.5**

Yields Of Beans (Kg/ha) Under Different Treatments From Some Sub-Counties Under Small Holder Ipm Cotton Project trials Summary In 2003

Tillage System		**Herbicide used to spray**		**Ploughed twice**	
Fertilizer Use		No NPK	NPK	No NPK	NPK
Farmer	**Sub-county**				
Ocen Olobo J.P.	Kaberamaido	1066.0	933.3	333.3	1200
Oligo Wilson	Obulubulu	520	520	566.7	586.7
Otiti Yokosafati	Alwa	60.0	133.3	33.3	120
Etoori-Elwoku S	Kalaki	433.3	533.3	133.3	300.0
Opio Laurence	Kangai	40	106.7	33.3	53.3
Opinya Patrick	Katine	100	193.3	120.0	160.0
Edou Faustine	Kamuda	80.0	126.7	86.7	86.7
Oluka Peter	Kyere	133.3	140	93.3	206.7
Ojakor John Bosco	Ongino	100.0	160.0	---	100
Opolot Alex	Mukura	86.7	80.0	100	100
Okodan Silver	Kanyum	366.7	566.7	333.3	433.3
Mugoda Mesulam	Kibuku	166.7	173.3	200.0	180.0
	SAARI	526.7	380.0	426.7	326.7
Mean	**---**	**283**	**311**	**189**	**296**

Yields Of Cotton (Kg/ha) Under Different Treatments From Various Sub-Counties Under Small Holder Ipm Cotton Project trials Summary In 2003

Tillage System		**Herbicide used to spray**				**Ploughed twice**			
Cropping System		Pure cotton		Inter-cropped with beans		Pure cotton		Inter-cropped with beans	
Fertilizer Use		No NPK	NPK	No NPK	NPK	No NPK	NPK	No NPK	NPK
Farmer	**Sub-county**								
Abuko Vicky	Kapujan	466.7	666.7	733.3	933.3	266.7	400	666.7	733.3
Inangolet Peter	Katakwi	666.7	1133.3	533.3	933.3	800	1066.7	800	1200
Akello Brenda	Toroma	453.3	413.3	466.7	466.7	340	593.3	466.7	266.7
Oligo Wilson	Obulubulu	1226.7	1953	1020.0	1333.3	1433.3	1400	1086.7	1560
Otiti Yokosafati	Alwa	933.3	633.3	600.0	1033.3	866.7	866.7	720	1200
Etoori-Elwoku S	Kalaki	1566.7	1700	1266.7	1533.3	733.3	1900	700	1900
Opinya Patrick	Katine	1866.7	2400	1800	1666.7	1766.7	2000	1666.7	1533.3
Edou Faustine	Kamuda	1400	1466.7	966.7	933.3	1266.7	1333.3	666.7	566.7
Oluka Peter	Kyere	333.3	666.7	400.0	400.0	1066.7	1133.3	666.7	466.7
Ojakor John Bosco	Ongino	866.7	1000	666.7	733.3	1133.3	1000	866.7	800
Opolot Alex	Mukura	666.7	666.7	466.7	600	733.3	800	600.0	733.3
Ojulong Papilio	Kapir	1533.3	1066.7	1000	1000	1400	866.7	933.3	1466.7
Okodan Silver	Kanyum	833.3	1200	466.7	693.3	1133.3	1266.7	533.3	366.7
Mugoda Mesulam	Kibuku	1466.7	1600	1066.7	1066.7	1466.7	1733.3	1200	1000
	SAARI	1266.7	1153.3	653.3	933.3	920.0	886.7	666.7	700
Mean	**----**	**1036**	**1181**	**820**	**951**	**980**	**1150**	**816**	**966**

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