PNAAQ083

REPORT TO THE BOARD OF GOVERNORS ON THE INSTITUTE'S WORK IN 1973–79

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RESOURCES ON
DEVELOPING COUNTRIES

FARM SYSTEMS AND INTERCROPPING PROGRAMME

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TABLE OF CONTENTS

Subject	Page
Introduction and highlights	
Intercropping	1 - 22
Gicci intercropping	1
Fertiliser responses in mixtures	13
Cereals - cowpea mixtures	15
Superimposed versus replacement mixtures	17
Crop geometry in mixtures	19
Residual effects from cereal/legume mixtures	22
Rotations and sequences	23
Sequence trial	23
Weed control and tillage	24 - 47
Introduction and highlights	24
Weed control in hoe farming systems	25
Weed control in animal powered systems	25
Striga ecological studies	35
Striga germination studies	37
Imperata control	42

Report to the Board of Governors of the Institute for Agricultural Research on Experimental Cropping Systems.

The programme is in three part and highlights of the first two parts, Intercropping and Rotations/Sequences, are given below. Highlights of the Weed Control and Tillage sub-programme are given on pages 24-25.

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Intercroppin/Rotations

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Intercropping and Rotations.

Three new projects were initiated during the year. The first attempts to produce an intercropping package by combining results from three successful mixtures. The mixtures were: cereals only; cereals and cotton; and cereals and cowpea. The object being to develop a five crop mixture, with cereals and cotton sown together, and cowpea sown later as relay, that maximises land use throughout the season.

The second new project is the very important one of developing fertiliser recommendations for use in mixtures. The argument being that if the response by crops in a mixture is not affected by companion crops then recommendations can be based on a simple pro-rata basis. However, first results show that maize in a mixture with cowpea yielded more than the sole crop at low levels of nitrogen (RYT = 0.83) compared with maize at higher levels of nitrogen (RYT = 0.54). Thus, at high levels of fertility there may be less gain from mixing.

The third new project begun aims to asses fertility changes with time for a rotation of mixed crops compared with a sole crop rotation. All evidence points to mixtures yielding better than sole crops and thus, by definition, must remove more from the soil.

Thus a rotation of mixed crops may require higher levels of inputs if fertility is to be maintained.

One project has been completed within the year, that of experiments with the 'gicci' system of intercropping. Results have shown clearly that the system has irreplaceable benefits over sole cropping. In particular the value obtained from having a flexible sowing date - population strategy more than outweighs recommendations for a high plant population which requires a later fixed date sowing. The system has shown that over 40% greater income can be obtained compared with the respective sole crop and the farmer has a greater element of choice in his strategy. Further, there is evidence of greater stability of return over a range of environments and seasons. Page 11 lists the choices available to the farmer for gicci groundnuts. In some cases, particularly where fertilised maize is used, returns are over 100% greater than those from sole groundnuts.

Other work, with cotton as the base crop, has shown that intercropping cotton with maize and groundnuts was more profitable than sole cotton, regardless of cotton sowing date. An interesting result from work with maize/cowpea is that a bigger advantage is obtained from mixing if the plants are grouped in double stands than if sown at a more usual single plant spacing.

Finally, the sequence trial, reported on page 23, has shown that yields which have declined with time can be partially recovered by careful use of fertiliser, although it was important to ensure a correct order of cropping. Particularly, sorghum should always follow groundnuts.

REPORT TO THE BOARD OF GOVERNORS OF THE INSTITUTE FOR AGRICULTURAL RESEARCH, AHMADU BELLO UNIVERSITY, 1978 - 1979.
EXPERIMENTAL CROPPING SYSTEMS, PROGRAMME 'H'.
INTERCROPPING
PROGRAMME H.I. 2/2.

GICCI INTERCROPPING

A well established system of farming by small farmers of the Northern Guinea Savannah zone is that known as 'gicci'. The system is one that arrives at a crop mixture in which one crop appears in widely spaced rows apparently at right angles to another crop. The essence of the system is that one crop is sown very early, with the first rain, on small heaps in the previous year's furrows. These heaps are made by taking a clump of soil from a ridge, using the 'galma' hoe, and depositing the heap in the furrow. The first crop is then sown on these heaps. Thus, the system takes advantage of early rain, minimises cultivation effort, doubles the depth of water in the soil under the crop, and produces small watersheds since the heaps crosstie at intervals along the furrows to make efficient use of early, erratic rainfall. Later, when the rains have established, the remainder of the ridges are split and a main crop sown along the ridge between the early crop. This system has been investigated in three phases during the period 1974 - 1979.

The first phase, done at IAR, has been to use groundnuts as the main crop in the system but with all crops sown at the same time. Phase two consisted of a series of State trials designed to confirm results over a range of environements. Finally, at IAR, the sowing date element of the system was investigated, together with the use of alternative main crops to groundnut. In these experiments the effects of both nitrogenous and phosphate fertilisers was investigated, as was whether the fertiliser should be applied to the early, minor, crop, or to the later, major, crop, or to both.

Results from the first phase showed clearly that not only was the system capable of giving greater cash returns than equivalent sole crops, but that even greater returns could be obtained when the minor crop was spaced closer than normal farmers' sowing, and that maize was a more profitable crop in the system than sorghum. These results are given in Table H.I/1. State trials of the second phase showed that gross cash returns from the system were never less than those from sole groundnuts, whilst, in many cases, gross cash returns were considerably higher than from the sole crop. Of considerable interest was that stability of return, measured by a regression technique, over years and environements was greater

for mixtures than for sole groundnuts in the Northern Guinea Savannah, where this particular cropping system is most widely practised. There was no difference in stability between sole groundnut and mixtures in either the Sudan or the Southern Guinea savannah. Near large towns, particularly in the Sudan zone, sole groundnuts was more profitable than mixed groundnuts. This was due entirely to the greater value of groundnut haulm from sole groundnuts. Results from these trials are given in Table H.I/2

Table H.I/1

Mean yields over three years of groundnut (unshelled), maize, millet and sorghum (grain at 14% m.c.) in kg ha^{-1} and total value in Naira (N).

Treatment.	G'nut	Maize	Millet	Sorgh	N
Sole groundnut	2441	-	-	-	352'
With maize at 1.37m	1957	1155	-	-	416'
With maize at 2.74m	2275	622	-	-	404'
With millet at 1.37m	2259	-	1209	-	536
With millet at 2.74m	2042	-	643	-	407
With sorghum at 1.37m	1696	-	-	1619	503
With sorghum at 2.74m	2180	-	-	883	411
" maize/millet at 1.37m	1989	421	874	-	490'
" maize/millet at 2.74m	2180	311	362	-	409
" maize/sorghum at 1.37m	1616	514	-	914	452'
" maize/sorghum at 2.74m	2057	196	-	364	373
" millet/sorghum at 1.37m	1851	-	588	796	496
" millet/sorghum at 2.74m	2241	-	343	340	433'
" maize/millet/sorghum at 1.37m	1914	350	838	515	541'
" maize/millet/sorghum at 2.74m	1957	204	392	213	411
			S.e.	±	N77.2

Six selected treatments (marked ' or '') in the Table above were used in the State trials of phase two of the programme. That treatment marked '', wide spaced millet and sorghum, was used as the 'standard' farmers' practice. Stability of return was measured by regressing the value of yield from individual treatments against sole crop groundnut yield for each location in each year. Thus, sole crop groundnut yield was used as an index of the environement. If the slope of the regression line (b) does not differ from that of the sole crop then stability of return is the same; if the slope is less, then stability is greater, and vice-versa.

Table H.I/2

Mean value in Naira(N) for sole groundnuts and groundnuts mixed with cereals, including value of cereal. All prices being those prevailing at harvest of each crop.

Location	Year	Sole	Mi/S	Ma	Ma/Mi	Ma/S	Ma/Mi/S	Se.±
Daura	76	180.5	176.1	171.2	199.6	159.4	169.5	33.7
T/Mafara	77	186.1	341.2'	149.4	437.2'	150.9	343.6'	51.3
K/Namoda	78	161.3	133.3	354.8'	240.4'	196.9'	200.4'	26.1
Kafinsoli	76	253.2	233.6	212.5	230.0	207.2	226.3	50.8
Batsari	76	61.5	95.6'	65.9	85.6	107.4'	115.7'	23.1
Batsari	78	35.9	36.6	36.6	55.7'	49.1	39.6	11.5
Gusau	76	380.9	368.2	535.2'	456.0	488.3	461.8	101.3
Gwarzo	78	76.5	131.7'	260.3'	184.6'	166.1'	189.3'	44.4
Mean Sudan		167.0	189.5	223.2	236.1	190.7	218.3	
% Gain			13.5	33.6	41.4	14.2	30.7	
b		0.17	0.16	0.19	0.17	0.18	0.17	
S.B.Gwari	76	123.1	141.6	107.0	112.1	121.9	135.3	27.2
S.B.Gwari	77	146.3	320.0'	255.4'	257.4'	387.9'	324.6'	49.4
Saminaka	76	220.6	205.3	221.1	202.1	229.5	213.6	61.8
Saminaka	77	217.7	255.8	298.7'	208.2	328.8'	346.7'	65.4
Saminaka	78	124.8	212.8	287.8'	250.8'	430.0'	344.7'	74.3
Mean N. Guinea		166.5	227.1	234.0	206.1	299.6	273.0	
% Gain			36.4	40.5	23.8	79.9	64.0	
b		0.18	0.05	0.10	0.02	-0.03	0.05	
Wawa	77	301.0	497.0'	503.2'	347.3	651.5'	458.1	80.2
Bida	76	194.7	187.4	214.6	262.7	318.0	367.3	128.9
Bida	77	95.2	118.0	170.0'	96.0	178.7'	147.3'	39.8
Keffi	76	467.3	432.9	522.6'	489.5	481.1	467.5	45.5
Mbatie	77	142.5	156.6	170.4	169.1	176.2	164.3	28.7
Mbatie	78	196.8	264.3'	152.0	172.9	252.7'	270.5'	44.6
Mean S. Guinea		232.6	276.0	288.8	256.3	343.0	312.5	
% Gain			18.5	24.0	10.0	47.3	34.2	
b		0.17	0.16	0.21	0.18	0.18	0.15	

There was no difference between regression coefficients (b) in either the Sudan zone, or between those in the Southern Guinea savannah, indicating that in these areas sole crop groundnuts was as stable in return as the mixtures. However, in the Northern Guniea savannah, where this particular cropping system is most widely practised, all coefficients for mixtures were very much smaller than that for sole groundnuts. This is an indication that the system may be more stable in this area.

In Phase 3 of these experiments sowing date was incorporated as a variable, as was also the effect of fertilisers to either cereals or groundnuts or both. Sowing date, particularly of cereals, is a very important component of the 'gicci' system; it is this which allows the farmer flexibility and gives him the capability to modify his cropping strategy according to season and other constraints. It is important to realise that such flexibility is not available to a sole crop farmer following, particularly, spacing recommendations. Because of the high plant populations usually recommended a farmer is unable to sow until rains are reliable, thus should there be a dry spell after sowing he may lose his crop. Sowing a low population at intervals early means that those crops are better established, require less water, and would survive.

The experiments consisted of 12 'systems', listed below:

1. Three sowing dates for cereals; groundnuts sown at the last date; no fertiliser to either crop.
2. As above, but groundnuts sown 2 weeks later.
3. As 1 above, but superphosphate fertiliser applied to groundnuts.
4. As 3, but groundnuts sown 2 weeks later.
5. As 1 above, but nitrogen fertiliser applied to cereals at sowing of cereals.
6. As above, but groundnuts sown 2 weeks later.
7. As 1, but superphosphate applied to groundnuts and nitrogen to cereals.
8. As 7, but groundnuts sown 2 weeks later.
9. As 1, BUT maize sown in place of groundnuts; no fertiliser applied.
10. As 9, but nitrogen applied to all cereals at sowing.
11. As 1, BUT sorghum sown in place of groundnuts and at the second sowing date; no fertiliser.
12. As 11, but nitrogen applied to all cereals at sowing.

Results are given in the following Tables.

System 1

Treatment	Cereal sowing date 1		2		3	
	Yield	N	Yield	N	Yield	N
Sole Groundnut					1102	319.6
Maize	226	79.1	719	215.7	Nil	-
Groundnut	892	258.7	883	256.1	744	215.8
TOTAL		337.8		471.8		215.8
GAIN		18.2		152.2		-103.8
Millet	8	2.8	5	1.8	Nil	-
Groundnut	514	149.1	1032	299.3	1031	299.0
TOTAL		151.9		301.1		299.0
GAIN		167.7		- 18.5		- 20.6
Sorghum	798	319.2	1225	490.0	165	66.0
Groundnut	602	174.6	516	149.6	938	272.0
TOTAL		493.8		639.6		338.0
GAIN		174.2		320.0		18.4

System 2

Treatment	Cereal sowing date 1		2		3	
	Yield	N	Yield	N	Yield	N
Sole Groundnut					830	240.7
Maize	403	141.1	664	232.4	Nil	-
Groundnut	751	217.8	531	154.0	654	189.7
TOTAL		358.9		386.4		189.7
GAIN		118.2		145.7		-151.0
Millet	5	1.8	4	1.4	Nil	-
Groundnut	468	135.7	645	187.1	746	216.3
TOTAL		137.5		188.5		216.3
GAIN		-103.2		-152.2		- 24.4
Sorghum	820	328.0	1912	764.8	219	87.6
Groundnut	350	101.5	304	88.2	595	172.6
TOTAL		429.5		873.0		260.2
GAIN		188.8		632.3		19.5

System 3(Mean results over 2 years).

Treatment	Cereal sowing date 1 Yield	N	2 Yield	N	3 Yield	N
Sole Groundnut					1296	341.4
Maize	296	96.6	346	113.6	52	15.8
Groundnut	1067	281.1	1050	304.6	1160	336.4
TOTAL		378.3		418.3		352.2
GAIN -		36.9		76.9		10.8
Millet	141	42.7	262	79.0	26	7.6
Groundnut	887	235.5	934	243.0	1177	310.8
TOTAL		277.2		321.9		318.5
GAIN		- 64.2		- 19.5		- 2.9
Sorghum	1312	439.2	1432	496.6	706	234.4
Groundnut	416	110.3	652	172.4	929	246.4
TOTAL		549.5		669.0		480.8
GAIN		208.1		327.6		139.4

(In all Tables including more than one year's results the TOTAL value may not correspond to the sum of the crop values. This is because values for each crop vary from year to year. The mean Totals and Gains are based upon the mean of the values of each crop in each year, not the value of the mean yields).

System 4

Treatment	Cereal sowing date 1 Yield	N	2 Yield	N	3 Yield	N
Sole Groundnut					846	245.3
Maize	373	130.6	684	239.4	Nil	-
Groundnut	578	167.6	536	155.4	748	216.9
TOTAL		298.2		394.8		216.9
GAIN		52.9		149.5		-128.4
Millet	12	4.2	24	8.4	Nil	-
Groundnut	478	138.6	643	185.6	819	237.5
TOTAL		142.8		194.6		237.5
GAIN		-102.5		- 50.4		- 7.8
Sorghum	692	276.8	1201	480.4	388	155.2
Groundnut	270	78.3	287	83.2	497	144.1
TOTAL		355.1		563.6		299.3
GAIN		109.8		318.3		54.0

System 5

Treatment	Cereal sowing date 1 Yield	N	2 Yield	N	3 Yield	N
Sole Groundnuts					1311	380.2
Maize	1092	382.2	1618	566.3	857	300.0
Groundnut	845	245.1	885	256.9	1100	319.0
TOTAL		727.3		823.2		619.0
GAIN		347.1		443.0		238.8
Millet	23	8.1	215	75.3	Nil	-
Groundnut	1023	296.7	762	221.0	1059	307.1
TOTAL		304.8		296.3		307.1
GAIN		- 75.4		- 83.9		- 73.1
Sorghum	440	176.0	1424	569.6	245	98.0
Groundnut	820	237.8	400	116.0	930	269.7
TOTAL		413.8		685.0		367.7
GAIN		33.6		305.0		-12.5

System 6

Treatment	Cereal sowing date 1 Yield	N	2 Yield	N	3 Yield	N
Sole Groundnut					1030	298.7
Maize	1300	445.0	1950	682.5	719	251.7
Groundnut	764	221.6	574	165.5	921	267.1
TOTAL		676.6		848.0		518.8
GAIN		377.9		549.3		220.1
Millet	6	2.1	238	83.3	Nil	-
Groundnut	784	227.4	624	181.0	637	184.7
TOTAL		229.5		264.3		184.7
GAIN		- 69.2		- 34.4		-114.0
Sorghum	312	124.8	1890	756.0	549	219.6
Groundnut	636	184.4	210	0.9	590	171.1
TOTAL		309.2		816.9		390.7
GAIN		10.5		518.2		92.0

System 7 (Mean results from 2 years).

Treatment	Cereal sowing date 1 Yield	₦	2 Yield	₦	3 Yield	₦
Sole Groundnut					1580	395.0
Maize	904	298.3	1010	341.9	518	207.0
Groundnut	1104	294.2	1106	294.4	1197	319.2
TOTAL		592.5		636.6		526.2
GAIN		227.6		271.7		161.3
Millet	218	63.0	295	90.0	14	4.0
Groundnut	781	207.2	1013	270.4	1296	345.8
TOTAL		270.2		360.5		349.8
GAIN		- 94.7		- 4.4		- 15.1
Sorghum	1400	464.2	2232	921.9	1054	376.7
Groundnut	700	190.8	674	182.9	1094	293.8
TOTAL		655.0		960.7		670.5
GAIN		290.1		595.8		305.6

System 8

Treatment	Cereal sowing date 1 Yield	₦	2 Yield	₦	3 Yield	₦
Sole Groundnut					840	243.6
Maize	1272	445.2	2392	837.2	553	193.6
Groundnut	761	220.7	798	231.4	677	196.3
TOTAL		665.9		1068.6		389.9
GAIN		422.3		825.0		146.3
Millet	18	6.3	83	29.1	Nil	-
Groundnut	606	175.7	598	173.4	731	212.0
TOTAL		182.0		202.5		212.0
GAIN		- 61.6		- 41.1		- 31.6
Sorghum	403	161.2	1835	734.0	868	347.2
Groundnut	434	125.9	350	101.5	553	160.4
TOTAL		287.1		835.5		507.6
GAIN		43.5		59.1		264.0

System 9: Maize sown in place of groundnut; no fertiliser.

Treatment	Cereal sowing date 1 Yield	₦	2 Yield	₦	3 Yield	₦
Sole maize sown at last sowing date					404	141.4
Maize	208	72.8	152	53.2		
Maize	360	126.0	677	237.0		
TOTAL		198.8		290.2		
GAIN		57.4		101.6		
Maize	Nil	-	Nil	-	650	227.5
Millet	8	2.8	5	1.8	Nil	-
TOTAL		2.8		1.8		227.5
GAIN		-138.6		-139.6		86.1
Maize	Nil	-	28	9.8	304	106.4
Sorghum	666	266.4	1512	604.8	250	100.0
TOTAL		266.4		614.6		206.4
GAIN		125.0		473.2		65.0

System 10: As above, but nitrogen applied to each cereal

Treatment	Cereal sowing date 1 Yield	₦	2 Yield	₦	3 Yield	₦
Sole maize sown at last sowing date					2661	931.4
Maize	2171	759.9	2143	750.1		
Maize	1549	542.2	1804	631.4		
TOTAL		1302.1		1381.5		
GAIN		370.8		450.2		
Maize	1037	363.0	512	179.2	968	338.8
Millet	8	2.8	184	64.4	Nil	-
TOTAL		365.8		243.6		338.8
GAIN		-565.6		-687.8		-592.6
Maize	1217	426.0	1051	367.9	1631	570.9
Sorghum	258	103.2	1041	416.4	527	210.8
TOTAL		529.2		784.3		781.7
GAIN		-402.2		-147.1		-149.7

System 11: Sorghum sown in place of groundnut; no fertiliser.

Treatment	Cereal sowing date 1 Yield	N	2 Yield	N	3 Yield	N
Sole sorghum sown at second sowing date			1697	678.8		
Sorghum	1494	597.6	1440	576.0	1451	580.4
Maize	374	130.9	118	41.3	Nil	-
TOTAL		728.5		617.3		580.4
GAIN		49.7		- 61.5		- 98.4
Sorghum	512	204.8	838	335.2	1227	490.8
Millet	3	1.1	5	1.8	Nil	-
TOTAL		205.9		337.0		490.8
GAIN		-472.9		-341.8		-188.0
Sorghum	521	208.4			1568	627.2
Sorghum	480	192.0			26	10.4
TOTAL		400.4				637.6
GAIN		-278.4				- 41.2

System 12: as system 11, but nitrogen applied to all cereals.

Treatment	Cereal sowing date 1 Yield	N	2 Yield	N	3 Yield	N
Sole sorghum sown at second sowing date.			1999	799.6		
Sorghum	1670	688.0	1742	696.8	1727	690.8
Maize	1085	379.8	946	331.1	48	16.8
TOTAL		1047.8		1027.9		707.6
GAIN		248.2		228.3		- 92.0
Sorghum	1400	560.0	1244	497.6	1655	662.0
Millet	Nil	-	132	46.2	Nil	-
TOTAL		560.0		543.8		662.0
GAIN		-239.6		-255.8		-137.6
Sorghum	1386	554.4			1402	560.8
Sorghum	216	86.4			68	27.2
TOTAL		640.8				588.0
GAIN		-258.8				-211.6

Results from the 1979 trial are not yet available. Table H.I/4 below summarises the results listed in the tables above.

Table H.I/4

Gross returns in Naira per hectare of sole crop and gains from using the gicci system

Treatment	Fertiliser			
	0	P	N	NP
Sole Groundnut(early)	320	341	380	395
+ maize sown D1.	+ 18	+ 40	+347	+228
+ maize sown D2.	+152	+ 77	+443	+272
+ maize sown D3.	-104	+ 11	+239	+161
+millet sown D1.	-168	- 64	- 75	- 95
+millet sown D2.	- 18	- 20	- 84	- 4
+millet sown D3.	- 21	- 3	- 73	- 15
+sorghum sown D1.	+174	+208	+ 34	+290
+sorghum sown D2.	+320	+328	+305	+596
+sorghum sown D3.	+ 18	+139	- 12	+306
Sole Groundnut(late)	241	245	299	244
+maize sown D1.	+118	+ 53	+378	+422
+maize sown D2.	+146	+150	+549	+825
+maize sown D3.	-151	- 28	+220	+146
+millet sown D1.	-103	-102	- 69	- 62
+millet sown D2.	-152	- 50	- 34	- 41
+millet sown D3.	- 24	- 8	-114	- 32
+sorghum sown D1.	+189	+110	+ 10	+ 44
+sorghum sown D2.	+632	+318	+518	+ 59
+sorghum sown D3.	+ 20	+ 54	+ 92	+264
Sole maize sown D3.	404		931	
+maize sown D1.	+ 57		+371	
+maize sown D2.	+102		+450	
+millet sown D1.	-139		-566	
+millet sown D2.	140		-688	
+millet sown D3.	86		-593	
+sorghum sown D1.	+125		-402	
+sorghum sown D2.	+473		-147	
+sorghum sown D3.	+ 65		-149	
Sole sorghum sown D2	679		800	
+maize sown D1.	+ 50		+248	
+maize sown D2.	- 62		+228	
+maize sown D3.	- 98		- 92	
+millet sown D1.	-473		-240	
+millet sown D2	-342		-256	
+millet sown D3.	-188		-138	
+sorghum sown D1.	-278		-259	
+sorghum sown D3.	- 41		-212	

There are certain preliminary inferences to be drawn from Table H.I/4:

1. Sole crop groundnut gave less gross return than either sole maize or sorghum whether or not fertiliser was used.
2. Sowing gicci millet to either early or late groundnuts, with or without fertiliser, gave consistent losses compared with sole groundnuts. This was because of excessive bird damage and, often, complete loss of millet grain. These trials were sown at IAR up to 5 weeks earlier than any other crop. Thus, there was no alternative source of grain for the birds. This would not necessarily be so in farmers' fields. The consequence was that grain could not compensate for groundnut loss due to competition from millet vegetation.
3. In the absence of nitrogen gicci sorghum gave considerable gains over sole crop groundnut, and was better than gicci maize. When nitrogen was applied to the cereals then the situation was reversed. Mean gain from maize was ₦30 and from sorghum was ₦224 in the absence of nitrogen. When nitrogen was used mean gain from maize was ₦353 and from sorghum was ₦209. Thus, if no nitrogen fertiliser is available use sorghum; if nitrogen is available, use maize.
4. Sowing either cereal very early, or at the same time as groundnut, gave lower gains than a medium sowing. Sowing early gave risk and stand loss due to variable moisture; sowing late gave greater competition to groundnut. However, sowing maize early may be best because of the potential for harvesting green maize, and thus removing competition almost entirely.
5. In the absence of fertiliser sowing gicci sorghum in maize gave gains over sole crop maize. However, when nitrogen was used sowing either sorghum or millet gicci in maize caused considerable losses.
6. Unless nitrogen was used sowing any cereal gicci in sorghum caused losses. When nitrogen was used, early and medium sow gicci maize was beneficial.
7. The most reliable system was to sow maize with fertiliser at the second sowing date, then the farmer has a choice of four; intersowing with main crop groundnut, early or late, or intersowing with maize or sorghum, giving nitrogen to the later sown cereals. These four systems consistently gave gains over the sole crops.

Two new series of experiments were started in 1979. The first of these considered fertiliser responses and the soil fertility relationships of mixed cropping. For some time questions have been asked as to whether response to fertilisers is the same in mixtures as in sole crops and the object of these trials is to provide a basis for recommendations for fertiliser use in mixed crops. The methodology is to compare the fertiliser response of several defined crop associations with the response of the component crop in monoculture. To assist in the interpretation of the yield results, detailed recordings of leaf cover are being made in the field. Secondly, the project aims to compare the cost:benefit of fertiliser in the two cropping systems. A third, and important, aim is to find out whether crop mixtures improve, maintain, or deplete soil fertility in comparision with a rotation of monocultures.

The first trial at Samaru is a detailed study of N, P and K responses in a maize-sorghum-cowpea association. Monoculture yields were greatly increased by nitrogen but in mixtures with sorghum the response by maize was smaller, although the interactions were not significant. Without nitrogen maize yielded 83% of that from the sole crop, despite having half the number of plants. With nitrogen maize yields were only slightly higher than the expected 50% of the sole crop. Early in the season leaf cover of the maize sorghum mixture was approximately equal to the mean monoculture value, irrespective of nitrogen application. These results are shown in Table H.I/5 below.

Table H.I/5

Maize yields, sole and in mixture, in kg ha^{-1}

Nitrogen applied(Kg ha^{-1})	Nil	50	100	S.e.±
Sole maize	2567	3972	4896	389
Maize with sorghum	2123	2126	2748	194
Maize relative yield	0.83	0.54	0.56	

(Samaru 123 maize sown 5 June 1979; P and K effects non-signif.).

A second trial has fewer NPK treatments but involves three associations: millet-sorghum-cowpea, maize-groundnut and maize-cotton. Associations will follow in sequence on the same area over time, as will an equivalent monoculture rotation. Millet yields were significantly increased by nitrogen, millet in the mixture giving a relative yield of 0.85 of the sole crop. However, the vigorous millet crop competed strongly with both sorghum and cowpea, which are not expected to yield well.

Samaru 123 maize had a poor monoculture yield in the absence of nitrogen, but responded well; the relative yield was high without notrogen. Groundnut yields in the mixture were significantly depressed by nitrogen (applied only to rows of maize) in the mixture - probably because of the more vigorous maize growth. The maize-groundnut mixture only showed an advantage over the sole crops (relative yield total greater than 1.0) when grown without nitrogen. Yields of TZE maize were low, especially in mixture with cotton. Table H.I/6 gives yields and relative yield totals.

Table H.I/6

Yields and relative yield totals

Nitrogen applied(Kg ha^{-1}) Yields in kg/ha grain.		Nil	60	S.e ±
Sole millet		1128	1576	193
Millet in sorghum		957	1358	96
Relative yield		0.85	0.86	
Sole maize		691	2244	138
Maize with groundnut		550	1284	69
Relative yield		0.80	0.57	
Sole groundnut	1272			47
Groundnut with maize		630	487	33
Relative yield		0.50	0.38	
Relative yield total		1.30	0.95	
Sole maize		887	1662	137
Maize with cotton		372	908	69
Relative yield		0.42	0.55	

(Ex Bornu millet sown 5 June 1979; Samaru 123 maize, in mixture with groundnut, sown 4 June; TZE maize, in mixture with cotton, sown 4 June; Samaru 38 groundnut sown 12 June. No nitrogen was applied to sole groundnut, and only to maize rows in the mixturo. P and K effects were not significant for any crop).

Early in the season millet-sorghum mixtures had greater leaf cover than mean monoculture value, irrespective of fertiliser. Thus, the mixture was more efficient at intercepting light.

Yield results so far indicate that the competitive relations of crops in mixtures may be altered by nitrogen application and these interactions must be understood before recommendations can be confidently made for mixtures. It is intended to extend this work to other locations in 1980.

Experiments aimed at comparing the performance of a cereal-cowpea mixture with the two crops grown sole were begun in 1977. Two sorghum varieties (HP3, short, and early maturing; YG5760, tall and late maturing) were grown sole and intercropped with two cowpea varieies of different plant type (2479, a spreading type, and both 341 and 29, semi-erect types). Sorghum was sown on the two inner ridges in each plot, whilst cowpea was sown on the out ridges. Half the experimental area was sprayed with Vetox 85 against insect pests, pest control was not done on the other half. Yield results are given in Table H.I/7.

Table H.I/7

Sorghum grain yields when grown sole and when mixed with cowpea.

	Sorghum variety		
	YG5760	HP3	Mean
Sole	2336	1238	1787
Mixed with cowpea 2479	3180	1626	2403
Mixed with cowpea 341	2581	1545	2063
Mixed with cowpea 29	3350	1594	2658
Mean	2862	1594	2228

YG5760 significantly outyielded HP3 whether grown sole or mixed. Though grain differences between mixed and sole sorghum appeared large they were not significantly different.

Table H.I/8 gives similar yields for cowpea varieties.

Table H.I/8

Cowpea yields when grown sole and when mixed with sorghum and relative yield totals.

	Cowpea variety			
Sprayed	2479	341	29	Mean
Sole	1014	1590	978	1194
Mixed with sorghum HP3	1499	1827	1169	1498
Relative yield total	1.40	1.19	1.24	
Mixed with sorghum YG 5760	1827	1115	1371	1438
Relative yield total	1.58	0.90	1.34	
Mean	1447	1511	1173	1377

Only when YG5760 was mixed with cowpea variety 341 was there a loss due to mixing; this mixture producing a relative yield total of 0.90 (that is 0.90 hectare of sole crop would produce the same total yield as 1.0 hectare of the mixture).

Table H.I/9 gives similar results for cowpea under unsprayed conditions.

Table H.I/9

Cowpea yields when grown sole and mixed with sorghum under unsprayed conditions and relative yield totals.

Unsprayed	Cowpea variety 2479	341	29	Mean
Sole	539	676	649	621
Mixed with sorghum HP3	1115	548	658	774
Relative yield total	1.69	1.03	1.15	
Mixed with sorghum YG 5760	914	566	420	633
Relative yield total	1.53	0.97	1.04	
Mean	856	597	576	676

Relative yield totals followed the same pattern whether the cowpea was sprayed or not. There was a slight indication that RYT increased under unsprayed conditions with the local cowpea variety 2479.

Further experiments were initiated in 1978 to compare the efficiencies of superimposed mixtures with those in which one component replaces another. For example, one row cowpea and one row cotton would be a replacement mixture, whereas two rows cotton, each undersown with one row of cowpea would be a superimposed mixture. In these trials maize, millet and groundnut sown sole in early June had cotton superimposed under each crop in June and July

Results are given in Tables H.I/10 and H.I/11.
Millet yields were low because of heavy rains at flowering, causing pollen wash and downy mildew, and later rain which caused heavy lodging at the pre-heading stage. Yields of June sown cotton was significantly reduced by all intercropping treatments except superimposed groundnut. Groundnut and maize yields were reduced by cotton. The maize-cotton association gave the highest return, followed closely by cotton-groundnut.

Table H.I/10

Yields of various crops as affected by June sown cotton intercropping and sowing pattern.

Treatment	Cotton	Millet	G'nut kernel	Maize	Gross income(₦)
Sole Cotton	1483				519
" Millet		229			82
" Groundnut			1511		907
" Maize				4052	1135
Cotton+Millet(Sub)	635	275			321
Cotton+Millet(Sup)	606	336			351
Cotton+Millet(SupPR)	394	229			220
Cotton+G'nut(Sub)	1067		893		909
Cotton+G'nut(Sup)	1471		847		1023
Cotton+G'nut(SupPR)	1046		618		737
Cotton+Maize(SupPR)	767			3503	1252
S.e.±	119.2	44.3	104.9	147.8	

(Sub = substitution; SP = superimposed on same ridge; SupPR = Superimposed in paired rows. Cotton @ 35k/Kg; Millet @ 36k/KG; Maize @ 28k/Kg.; Groundnut @ 60k/Kg.)

Table H.I/11

Yields of various crops as affected by July sown cotton intercropping and sowing pattern.

Treatment	Cotton	Millet	G'nut kernel	Maize	Gross income(₦)
Sole cotton	1757				615
" millet		298			107
" groundnut			1328		797
" maize				4279	1198
Cotton+Millet(Sub)	601	229			293
Cotton+Millet(Sup)	291	275			201
Cotton+Millet(SupPR)	500	252			266
Cotton+G'nut(Sub)	796		1351		797
Cotton+G'nut(Sup)	749		1305		1089
Cotton+G'nut(SupPR)	823		1099		947
Cotton+Maize(SupPR)	521			4258	1374
S.e.±	108.5	60.2	172.7	106.2	

Yields of cotton were reduced by all crops, particularly by millet when cotton was superimposed; there was little difference between the patterns of intercropping. Table H.I/12 gives yields of cotton as they were affected by different crops and patterns.

Table H.I/12

Yields of June and July sown cotton as affected by intercrops

Treatment	June sown	July sown	Mean
Sole Cotton	1483	1757	1620
Cotton+Millet(Sub)	635	601	618
Cotton+Millet(Sup)	626	291	458
Cotton+Millet(SupPR)	394	500	447
Cotton+Groundnut(Sub)	1067	796	932
Cotton+Groundnut(Sup)	1471	749	1110
Cotton+Groundnut(SupPR)	1046	823	934
Cotton+Maize(SupPR)	767	521	644
Mean	936	755	

Sole crop July sown cotton outyielded June sown sole cotton. However, July sown cotton intercropped yielded less than intercropped June sown cotton. This was a simple effect of competition from established crops when cotton was sown a month after them, in July. Groundnut showed to be the crop most compatible crop for intercropping with cotton.

Table H.I/13 gives yields of the other crops as affected by cotton sowing date.

Table H.I/13

Yields of millet, groundnut and maize as affected by cotton s.date.

Treatment	June sown	July sown	Mean
Sole Millet			263
+Cotton(Sub)	275	229	252
+Cotton(Sup)	336	275	321
+Cotton(SupPR)	229	252	240
Mean	275	263	
Sole Groundnut			1419
+Cotton(Sub)	893	1351	1122
+Cotton(Sup)	847	1305	1076
+Cotton(SupPR)	618	1099	858
Mean	967	1271	
Sole maize			4167
+Cotton(SupPR)	3503	4270	

Maize yields were significantly reduced by sowing at the same time as cotton.

Conclusions from this experiment are summarised below.

1. Intercropping cotton with groundnut and maize was more profitable than sole cotton, regardless of cotton sowing date.
2. Cotton and groundnut showed to be the most compatible mixture, giving a land equivalent ratio of 1.50.
3. At prevailing market prices the most profitable mixture was cotton and maize.

In the preceding experiments attempts were made to consider the effect of interrow pattern upon response to intercropping. In the following work the effects of intrarow pattern were investigated.

There were two series, one involving sorghum and cowpea the other maize and cowpea. The effects of grouping on yield in mixtures was studied by alternating groups of one, two or three plants of each crop along the row. Spacings used were double and triple that used for single plants, thus plant population per unit area was constant. Yield results are given in Tables H.I/14 and H.I./15.

These studies have suggested that a recommendation for single plant stands in mixtures may not be best for maximising yield. Where sorghum-cowpea was concerned double plant stands not only gave the highest total yield but also gave a good contribution from each component, thus satisfying the farmers' need for variety. Similarly, in the maize cowpea mixture the best total yield came from double plant stands. In this mixture gross returns from the double plant stand arrangement was ₦1061, compared with ₦932 and ₦893 for single plant stands and triple plant stands respectively. The same patter emerged from the trial at Mokwa, although yields were lower than those at Samaru. Further, whilst there was no difference in yield of sorghum due to plant arrangement, yield of cowpea was almost doubled when multiple plant stands were used compared with single plant stands. Cowpea also yielded more when mixed with maize than when mixed with sorghum, probably because of the less dense canopy compared with sorghum, and because the two crops were in competition for a shorter period.

Table H.I/14

Yields and gross cash returns from a sorghum-cowpea mixture

Treatment	Samaru Sorghum	Samaru Cowpea	Samaru ₦	Mokwa Sorghum	Mokwa Cowpea	Mokwa ₦
FFBL/Ife Brown						
Single	3774	79	698	3318	40	607
Double	3862	144	730	3206	92	599
Triple	3474	105	650	2879	96	541
FFBL/180						
Sihgle	3869	65	712	3264	58	602
Double	4003	128	752	3471	99	649
Triple	3561	91	663	2919	76	543
SK5912/IfeB.						
Single	4283	96	794	3774	63	694
Double	4252	184	809	3693	127	696
Triple	3670	153	698	2997	116	568
SK5912/180						
Single	4019	87	744	3906	56	716
Double	4123	129	773	3862	91	714
Triple	3542	143	672	3301	93	616

(FFBL and SK5912 = sorghum varieties; Ife Brown and Var 180 = cowpea varieties. Marketing prices of ₦180 and ₦240 per tonne for sorghum and cowpea respectively).

Table H.I/15

Yields and gross cash returns from a maize-cowpea mixture

Treatment	Samaru Maize	Samaru Cowpea	Samaru ₦	Mokwa Maize	Mokwa Cowpea	Mokwa ₦
BL/Ife Brown						
Single	4802	520	989	4492	405	906
Double	4732	900	1068	4316	673	939
Triple	4016	686	888	4068	536	861
BL/Var 180						
Single	4439	632	951	4372	415	887
Double	4528	1228	1110	4467	700	972
Triple	4246	743	942	3886	608	846
S123/Ife Brown						
Single	3596	969	870	3585	392	739
Double	3892	1342	1023	3444	789	809
Triple	3667	982	896	3196	573	713
S123/Var180						
Single	3621	1101	916	3462	500	743
Double	3879	1429	1041	3257	819	783
Triple	3541	868	845	3085	632	707

(BL = Bomo Local maize, S123 = maize; maize @ ₦180 per tonne).

The maize-cowpea association was also studied in another experiment with the aim to find plant charactors compatible for mixing. Two varieties of maize were used; Bomo local, an improved local variety of short stature (2m) and early maturing (90 days), and S123, a Samaru constructed composite of three maize lines, taller than Bomo local and maturing after 110 days. These were mixed in all combinations with two cowpea varieties. These were Ife Brown and V1696. Both are determinate and photosensitive, but Ife Brown is semi-erect whilst V1696 is spreading and climbing, this variety also matures later than Ife Brown.

Cowpea was sown as a superimposed mixture, being sown three weeks after maize and between plants of a full stand of maize. Table H.I/16 and H.I/17 gives the results.

Table H.I/16

Grain yield, gross return, and plant attributes of maize and cowpea

Treatment	Maize	Cowpea	Gross return	100 seed weight Maize	Cowpea
Sole Bomo local	3480		626	259	
" Samaru 123	3913		704	235	
Sole Ife Brown		1192	286		146
" V1696		986	237		189
BL/Ife Brown	3392	582	751	283	147
BL/V1696	3046	613	695	278	173
S123/Ife Brown	3803	193	731	235	144
S123/V1696	3756	505	797	229	175

(Maize @ ₦180 and cowpea @ ₦240 per tonne. 100 seed weight is weight in grammes of 100 seed).

Table H.I/17

Other attributes of maize and cowpea

Treatment	No grain m^2 maize	Seed/ pod cowpea	Pods/ m^2 cowpea	Branches/ m^2 cowpea	Lodging % maize
Sole Bomo local	1864				1.0
" Samaru 123	2469				0.0
Sole Ife Brown		9.5	28.3	14.2	
" V1696		5.7	17.5	9.4	
BL/Ife Brown	1739	8.1	11.4	10.3	1.3
BL/V1696	1784	5.9	9.6	6.9	4.3
S123/Ife Brown	2372	3.2	4.0	1.2	0.0
S123/V1696	2261	5.1	9.8	5.8	2.2

Samaru 123 outyielded Bomo local both as sole crop and when mixed with cowpea. There was no such difference from the cowpea. The higher yield from Samaru 123 was attributed to a greater number of grain per unit area; there was no difference in seed size. Yields of both maize varieties was only slightly reduced by mixing, but cowpea yields were considerably reduced. The local variety, V1696 was not affected differently by the maize varieties, but the yield of Ife Brown was much more reduced by the longer season maize, Samaru 123, than by Bomo local. There was an indication that the climbing variety, V1696, increased lodging in both mazie varieties.

One attribute of mixtures which has hitherto been given little attention is the possible beneficial residual effect on succeeding crops of legumes in legume-cereals mixtures. To investigate this problem a trial was begun in 1976 using sole maize grown sole, with and without nitrogen, and with soybean or cowpea also with and without nitrogen. This trial was followed by sole maize only in both 1977 and 1978. Results are given in Table H.I/18

Table H.I/18

Yields of cowpea and soybean for 1976; maize yields for 1976-78

Treatment	1976	1977	1978	Total maize	yield. Mean
Sole maize	2693	2108	2476	7277	2426
Sole maize + nitrogen	3560	2308	2540	8408	2803
Maize + soybean	2826	2550	2368	7744	2581
Maize + soybean + N	3332	2555	2628	8515	2838
Maize + cowpea	1813	2362	2550	6725	2242
Maize + cowpea + N	2816	2231	2420	7467	2489
Sole soybean	1956	4365	2909	7274	3637
Sole cowpea	555	4069	2815	6884	3442

Results would appear to indicate that the effects of nitrogen do not extend beyond the year of application; that there was a residual effect from sole legumes which showed in the following year only. Effects from the legume within the mixed crop are unclear, this is because treatments were confoundod with plant population. Legumes constituted one third, and maize two thirds, of the total population.

H.II ROTATIONS AND SEQUENCES

Two experiments are being carried out under this head. The first, which aims at determining the best sequence for growing sorghum, cotton and groundnuts, and which started in 1972, completed the first phase in 1975. The results, given in Table H.II/1, showed that the best sequence in terms of crop yield was groundnuts, sorghum and cotton in succession.

Table H.II/1

Effects of cropping sequence on yields of sorghum, cotton, groundnuts.

Test crop	Year	After Sorghum	After G'nuts	After Cotton	LSD @ 5%
Sorghum(Grain)	1973-74	2474	3564	2982	383
	1974-75	1908	2625	2283	234
	1975-76	1236	2070	1886	280
With increased fertiliser	1976-77	1463	2970	1850	287
	1977-78	1482	2670	2291	740
Groundnuts (kernels)	1973-74	2292	1454	2181	260
	1974-75	1344	1201	1280	110
	1975-76	529	400	584	121
With increased fertiliser	1976-77	1685	1492	1410	118
	1977-78	1352	1007	1170	198
Seed Cotton	1973-74	1586	1026	1126	187
	1974-75	933	809	658	183
	1975-76	850	479	503	343
With increased fertiliser	1976-77	1501	1725	2053	446
	1977-78	1355	1796	1485	431

For the years 1973-76 fertiliser applied to the crops was nominal (10kg/ha P to all crops; 29kg/ha N to sorghum and cotton in each year). Results clearly showed a decline in yield with time. For the years 1976-78 fertiliser rates were increased (20kg/ha P to all crops, 58 kg/ha N to sorghum and cotton, and 500 kg/ha of agricultural lime). The table shows that these amounts of fertiliser were sufficient to arrest the declining yields with time and the second phase of this programme has been designed to investigate whether annual applications of fertiliser can be replaced by heavier doses at shorter intervals. Four levels of phosphate were used (0, 50, 100 and 200 kg/ha P) applied to each of four cropping sequences. These are: Continuous cotton; continuous groundnut; cotton alternating with groundnut; groundnut alternating with cotton. In the fifth year following these sequences each plot will be tested with maize.

Sub-Programme H. III. Weed Control and Tillage

As common with other research programmes the amount of zonal field experimentation was severely limited by lack of funds for touring, transport and equipment.

Zonal testing of herbicides for weed control in partially-mechanised sole crops continued for a second season. The detailed results are reported for the individual crops under the appropriate commodity crop committees. Certain general trends are now becoming clear.

1. The profitability of pre-emergent herbicide use is greatly improved by thorough seedbed preparation. This type of application cannot be used to compensate for bad tractor cultivations.

2. A single well-timed hoe weeding is usually very profitable in the presence of herbicide.

3. Though pre-emergent herbicides may give profitable weed control without supplementary post-emergent weed control, it is already evident that late maturing weeds may build up and cause economic losses under the partially mechanised system. This may well be the reason for the rapid spread of Rottboellia, which has previously been an unimportant weed in the traditional hoe farming systems.

4. There is therefore a need for supplementary weed control techniques which will facilitate the control of late maturing weeds. This has already been effectively done for the animal power system with the development of high clearance straddle row cultivators at Samaru. (See section H. III/32.i of this report).

5. It is however necessary to develop crop rotations which interrupt the life cycle of late maturing weeds of potential economic importance as an integral feature of weed control in the partially mechanised system and to investigate the possibility of full mechanisation with standard tractors in low growing crops like groundnuts (see H 3/3 of the oilseeds research committee).

6. Pending the availability of precision ground metered VLV sprayer prototypes, no major new projects were started in the hoe farming system but it is probable that the handpulled 'punch' planters developed at IITA for zero-tillage crop residue mulch cultivation in the forest zone could be integrated into a 'stale seedbed' low energy cultivation system for hoe farmers in the savanna zone where tsetse infestation precludes the use of animal power. Applications comparing glyphosate with paraquat for zero-tillage crop establishment in 1979 indicate a very considerable technical advantage to glyphosate.

Screening of herbicides for the maize/sorghum/yam mixture continued at Mokwa.

7. Testing of the synthetic strigol analogue GR45 during 1978 confirmed that this material (like GR7 and GR28 tested in 1977) is a very active and persistent striga germinator. The late arrival of the experimental material for a second

season made it impossible to demonstrate the full economic potential of these materials to increase grain yield on striga infested sites. Ethepon (used as a source of ethylene) was shown to be an active striga germinator in 1971 (Report to the Borad of Governors 1972) but it was then far too expensive for commercial use. Relative price changes now make it profitable to use in maize production on heavily striga infested sites in the presence of suitable herbicides.

Sub-Project H.III/3/3. iv. Weed Control in the Hoe Farming System Weed Control in Yam/Maize/Cowpea Mixture.

by

S. T. O. LAGOKE.

Three preliminary experiments were conducted in this trial, to identify suitable herbicides in sole crop yam, yam/maize mixture and cowpea. In sole crop yam, Flumetoron at 2 kg/ha and Ametryne/Alachlor mixture (1:3) at 4 kg/ha resulted in tuber yields that were comparable with the best hosweeded check. These treatments also controlled weeds effectively up to 16 weeks of crop growth. Also promising, were Metolachlor at 4 kg/ha. Linuron/Metolachlor mixture (1:3) at 4 kg/ha. Atrazine/Alachlor and Atrazine/metolachlor (1:3) at 4 kg/ha, Ametryne at 2 and 4 kg/ha. In the yam/maize mixture, Atrazine/metolachlor mixture (1:2) at 4 kg/ha resulted in the best yam tuber and maize yield, although season-long weed control was not effected by this treatment. Both Chloramben at 2 kg/ha, Prometryne and Metolachlor at 3 kg/ha resulted in very high cowpea yield. These treatment combinations are now being tested in yam/maize/cowpea mixture in the current season.

Sub-Project H.III/3/2.i. Weed Control in Animal Powered Farming Systems

Weed control with animal power in cotton (CI/3/3.6) A comparison of cultivation System. J. Ogborn.

The 1978 season was the first in which the single purpose 'Straddle row rotary cultivator' (SRRW) developed at IAR Samaru was available for agronomic testing for comparison with the locally manufactured 'STRAD' rotary cultivator.

The light simple technology design of the SRRW requires also the use of a ridger for primary ridge-splitting and a seed drill. In contrast the STRAD is fitted with propriatory high technology 'slicer time' rotors and a fixed central time to enable it to perform primary ridge cultivation at the start of the rains without ridge splitting.

Table H. III/3/1 - Weed Control in Yam.

Treatments	Kg a.i./ ha	1st vigour score at 6th wk.	2nd vigour score at 12th wk.	3rd vigour score at 18th wk.	4th Vigour score at 24th wk.	Total Tuber weight t/ha	Marketable Tuber Wt. t/ha	WEED SCORE: WEEKS AFTER PLANTING. at 6th week.	at 8th week	at 12th week	at 16th week	Weight of weeds at 16 wks kg/ha	Weight of weeds at Harvest kg/ha
Fluometuron	4.0	4.00	8.50	9.50	8.50	17.67	8.73	1.08	1.83	4.00	5.67	1595	7025
Fluometuron	2.0	6.67	10.00	10.00	8.50	19.80	14.27	3.75	6.17	5.83	7.83	2626	5775
Fluometuron + metolachlor	2 + 2	6.00	9.33	9.50	8.67	16.87	11.10	4.67	6.33	6.83	8.33	2728	3683
Flurometuron + metolachlor	1 + 3	6.33	9.00	10.00	8.67	17.97	9.87	2.00	5.00	5.83	6.67	3112	4783
Fluometuron + Alachlor	2 + 2	4.00	8.67	9.67	8.00	15.03	5.53	3.08	5.50	7.50	9.17	2792	7967
Fluometuron + Alachlor	1 + 3	3.50	8.33	9.17	8.00	15.53	8.27	0.92	1.83	5.83	8.33	2103	6145
Atrazine	4	4.67	8.50	9.17	7.00	13.77	5.43	1.17	5.00	6.50	8.33	3213	2717
Atrazine	2	4.00	8.67	9.53	7.50	17.07	8.93	5.52	5.33	7.83	8.67	3064	6325
Atrazine + metolachlor	2 + 2	4.33	9.17	10.00	8.83	16.73	6.40	1.42	3.17	5.83	8.00	2045	5350
Atrazine + metolachlor	1 + 3	5.67	9.33	10.00	8.83	17.53	9.33	1.83	6.00	6.00	7.33	2809	8533
Atrazine + Alachlor	2 + 2	2.67	7.00	8.67	7.67	14.53	4.27	0.25	1.58	5.17	7.50	2608	8275
Atrazine + Alachlor	1 + 3	5.33	9.33	10.00	8.67	17.33	9.27	3.00	3.67	7.50	9.00	2431	7508
Linuron	4	4.67	9.50	9.67	8.33	16.73	8.67	2.42	2.50	5.17	7.50	1019	6483
Linuron	2	4.00	7.33	9.83	8.17	15.50	8.47	6.67	6.17	7.83	9.00	7356	8142
Linuron + metolachlor	2 + 2	4.67	8.67	9.67	8.50	16.87	6.40	3.00	2.67	6.17	7.33	2433	8508
Linuron + metolachlor	1 + 3	4.67	8.67	9.50	8.50	17.93	9.20	0.58	2.67	4.00	5.83	2928	5642
Linuron + Alachlor	2 + 2	6.00	9.00	9.67	7.83	14.97	6.57	1.42	3.50	6.83	8.67	1245	12033
Linuron + Alachlor	1+3	4.33	8.33	9.17	7.50	14.40	6.40	2.75	2.50	6.00	8.17	3544	5383
Metolachlor	2	5.67	9.33	9.33	8.50	15.27	10.00	3.92	5.00	6.33	8.50	1760	5675
Metolachlor	4	4.33	9.12	10.00	8.50	18.80	9.67	2.17	4.50	5.00	6.33	2761	5817
Alachlor	2	5.00	8.83	9.67	8.17	13.83	7.63	5.33	6.17	8.17	9.33	3977	9033

Treatment	kg a.i/ ha	1st Vigour score at 6th wk.	2nd Vigour score at 12th wk.	3rd Vigour score at 18th wk.	4th Vigour score at 24th wk.	Total Tuber weight t/ha	Marketable Tuber wt. t/ha	WEED SCORE: WEEKS AFTER PLANTING. at 6th	at 8th week	at 12th week	at 16th week	Weight of weeds at 16 wks. kg/ha	Weight of weeds at harvest kg/ha.
Alachlor	4	3.67	8.67	9.67	9.00	16.40	8.57	1.25	3.00	5.67	7.33	2726	3667
Ametryne	4	4.33	8.83	9.83	8 83	18.90	9.30	1.00	4.50	4.67	5.50	1186	6250
Ametryne	2	4.00	9.17	9.83	9.00	17.93	9.00	2.58	2.58	5.00	5.83	2235	5250
Ametryne + Alachlor	2 + 2	3.67	8.00	9.50	8.67	19.27	11.33	0.67	3.33	3.17	5.50	2797	5263
Ametryne + Alachlor	1 + 3	6.67	9.00	10.00	9.67	19.53	12.13	4.42	6.00	5.50	6.83	2832	6983
Weed free		4.00	8.33	10.00	8.83	22.07	13.13	3.92	2.83	2.33	1.33	516	567
Hoeweeding for 4,8,16 weeks		6.67	9.67	10.00	10.00	23.67	16.20	3.67	0.50	2.50	5.00	0	383
Unweeded		3.00	8.33	8.33	7.33	12.47	4.40	6.83	7.33	9.00	9.50	3653	9500

Table H.III/3/1 Weed Control in Cowpea

Treatment	Kg/ha	Weed score at 6 weeks	Vigour score at 7 weeks	Grain yield kg/ha
Alachlor	1.5	1.0	7.5	1058.94
Alachlor	3.0	0.25	5.5	759.31
Metolachlor	1.5	0.92	5.7	1243.91
Metolachlor	3.0	1.92	5.8	1366.34
Chlorobromuron	1.5	4.33	8.3	1162.11
Chlorobromuron	3.0	2.5	6.3	412.34
Chloroxuron	1.5	3.67	2.5	259.17
Chloroxuron	3.0	5.08	5.2	680.52
Prometryne	1.0	2.08	8.3	1058.94
Prometryne	2.0	4.67	9.2	1411.92
Ametryne	1.0	1.75	7.7	850.57
Ametryne	2.0	0.67	7.5	546.61
Linuron	1.0	2.5	9.3	1050.46
Linuron	2.0	1.25	7.8	914.07
Norflurazone	0.8	3.5	9.0	1142.33
Norflurazone	1.6	0.83	8.8	1112.29
EL-171	0.25	1.5	6.7	673.10
EL-171	0.5	1.83	2.0	21.91
Diuron	0.8	1.25	9.2	1071.31
Diuron	1.6	1.5	8.8	1183.31
Fluorodifen	1.5	2.58	8.0	829.98
Fluorodifen	3.0	0.5	8.7	1219.00
Hand weeding at 3 and 6 weeks		9.17	9.7	1234.55
Hand weeding at 3, 6 & 9 wks.		6.83	9.2	1484.35
Unweeded		6.5	7.5	1049.75

The contrast was therefore between a high technology MULTI purpose toolbar which prepared seedridges by reduced tillage leaving the core of the ridge undisturbed and a combination of SINGLE purpose units preparing ridges conventionally as set in table H.III/3/2.1. These single purpose units all required two operations.

Table H.III/3/2.1 Specification of tillage systems 1978

Operation	Systems	
	MULTI	SINGLE
Primary cultivation	Rotary 5/4/78	Ridges split by ridger 23/5/78
Herbicide application	GMSD sprayer on 5/4/78 and 2/8/78 (start)	GMSD sprayer on 3-7/6/78
Herbicide incorporation	During primary cult.	SRRW rotary in 3-7/6/78
Seedridge preparation	Rotary 26/6/78	No-herbicide ridges split on 27/6/78.
Seed sowing	By sowing tube during seedridge preparation 26/6/78.	By seed drill in separate operation 27/6/78
Crop thinning spot hoeing of the crop row.	10-12/7/78	13-21/7/78
Straddle cultivation as required from:-	10/7/78	11/7/78
Hoe weeding in crop row as required from:	8/8/78	14/8/78
MSMA post-emergent herbicide applied by GMSD	2/8/78	2/8/78

Design: 2. cultivation system applied to 16 main plots.
X
7. herbicide treatments applied to 120 sub-plots

Plots size: Main Gross = ha/23.1
Sub. Gross = ha/284.8 Net = ha/478.4

Treatments

	Symbol
MULTI purpose STRAD system	MULTI
vs	
Combination of SINGLE purpose ridger, SRRW and seed-drill	SINGLE
x	
Herbicide treatments (dosage as kg ai/ha applied in 10 l/ha by GMSD sprayer)	
No herbicide (double replication)	CHECK
trifluralin 0.8	trf. 0.8
trifluralin 1.2	trf. 1.2
trifluralin 0.4	din. 0.4
MSMA 1.2	MSMA

General Crop Agronomy.

11/8/78	1st insecticide application (ULVA)
19/9/78	2nd " " [1]
26/9/78	3rd " "
2/10/78	4th " "
9/10/78	5th " "
22/11/78	Picking started on MULTI system
4/12/78	Picking started on SINGLE system
10/1/79	Cotton picking completed.

Note. [1] Delayed by supervisory error

Results:

Measurements of machine hours

Where operations could be performed on main plots which were 113m long, the actual times per main plot were used. For operations on individual sub-plots a value was estimated by deducting the 'turning time' estimated by a sample of about 2 individual runs on single ridges. The times for the SRRW operations were further adjusted by deducting 'roter cleaning time', because the scrapers for this machine were still under development.

Measurements of labour h

All operations using hoe labour were recorded individually on sub-plot to the nearest second. They have not been adjusted for plot size.

Analysis

One SINGLE system main plot had to be abandoned as 'too weedy'. This left a non-orthogonal design.

Table H. Crop establishment input including thinning and weeding (Table H.III/3/2.2)

Treatment	Machine time (hr/ha)				Man hours/ha	
	Prim. Cult.	Herb. Inc.	Sowing prep.	Thinn. Cult.	Operator	Hoe Labour
MULTI System						
CHECK	6.8	-	11.7	8.2	27.0	77.8
Her. Means	-	6.8	7.2	8.2	22.2	38.7
trf. 0.8	-	6.8	7.0	8.2	22.0	39.4
trf. 1.2	-	6.8	8.0	8.2	23.0	49.7
din. 0.4	-	6.8	6.7	8.2	21.7	27.1
System means	6.6.8		8.3	8.2	23.4	48.5

Treatment	Machine time (hr/ha) Prim. Cult.	Herb. Inc.	Sowing prep.	Thinn. Cult.	Man hours /ha Operatpr	Hoe Labour
SINGLE system						
CHECK	13.6	-	9.3	19.4	84.6	131.0
Herb. means	13.6	8.0	9.3	9.1	80.0	42.5
trf. 0.8	13.6	8.0	9.3	9.0	79.8	47.3
trf. 1.2	13.6	8.0	9.3	9.6	81.0	54.1
din. 0.4	13.6	8.0	9.3	8.7	79.2	26.0
Systems means	19.6		9.3	11.6	81.0	64.6

Table H.III/3/2.3 Post thinning weed control

The 'Days of complete control' (after thinning) provided the only comparison of the performance of the roters. In the absence of a herbicide, the 'slicer time rotors' on the STRAD controlled weed regrowth for 8 days longer than the 'picker time' rotors on SRRW. In the presence of herbicides however, the system difference became very small.

Table H.III/3/2.3 Post thinning weed control

	Stands 000/ha	Days of complete control	Machine time hr/ha	Man hours /ha Operator	Hoe labour August	Sept.
MULTI Systems						
CHECK	53.8	27.2	13.9	13.9	100.9	36.9
Herb. means	55.6	39.2	10.9	12.0	48.0	58.5
trf. 0.8	52.9	37.4	12.9	13.8	74.8	102.2
din. 1.2	57.2	28.5	13.6	13.6	64.4	58.1
din. 0.4	53.6	41.8	10.6	10.6	55.0	10.5
trf. 0.8 + MSMA	57.7	41.2	10.3	12.0	32.7	98.1
trf. 1.2 + MSMA	55.9	44.8	7.5	7.5	18.1	38.2
din. 0.4 + MSMA	56.6	41.6	10.5	14.2	43.0	44.0
System means	56.2	36.4	11.8	12.5	63.7	57.9

SINGLE System

Treatment	Stands 000/ha	Days of Complete control	Machine Time hr/ha	Man hours /ha Operator	Hoe labour Augst	Hoe labour Sept.
CHECK	55.9	19.3	7.7	15.4	129.1	54.0
Herb. means	57.0	36.6	3.9	8.8	67.9	125.3
trf. 0.8	56.0	28.5	5.5	11.0	58.5	116.3
trf. 1.2	54.1	25.6	5.9	11.8	92.4	123.5
din. 0.4	60.5	39.5	2.9	7.3	94.4	123.5
trf. 0.8 + MSMA	56.0	44.3	3.0	9.2	61.2	126.8
trf. 1.2 + MSMA	56.3	31.2	4.5	9.0	85.8	124.3
din. 0.4 + MSMA	59.[illegible]	50.6	1.6	4.2	15.0	137.3
Systems means	56.8	32.6	4.9	10.4	83.2	111.5

The major difference between the systems was the consistently higher hoe labour requirement on the SINGLE system during August and September for weed control in the crop row. As less machine cultivation was required to control weed between the crop rows it would appear that the higher weed challenge in the row must be due to less effective seed ridge preparation.

Crop total profitability (table H.III/3/2.4.

There were no marked systems differences in crop vigour but herbicides generally increased crop vigour (measured by dry shoot wt.). In the absence of herbicides the SINGLE system significantly ($P = .018$) outyielded the MULTI system but this effect was reversed in the presence of herbicides. In both systems the highest yielding herbicide treatment was trifluralin 0.8 while the higher dosage consistently yielded less.

Crop establishment Table H.III/3/2.2)

Both sets of dinitramine plots were weed free and only required thinning. The consequent reduction in sport weeding more than paid for the cost of this herbicide. Apart from the increase in operator hours caused by two-man operation the SINGLE system units all travelled slightly slower, apparently because they all required at least one walking operator. The herbicides markedly reduced the amount of spot weeding required in both systems. In the absence of herbicides an average of over two passes were required with the SRRW. Only one was required in the presence of dinitramine and an average of just over one was needed in the presence of trifluralin.

One pass with the STRAD was enough in all treatments. The trifluralin 1.2 treatments gave markedly poorer weed control than the lower dosage. This might have been caused by poorer droplet formation of this very concentrated emulsion by the GMSD.

Table H.III/3/2.2 Crop establishment input including thinning and weeding.

Table H.III/3/2.2 Crop establishment input including thinning and weeding.

Treatment	Machine time (hr/ha)				Man hours/ha	
	Prim. Cult.	Herb. Inc.	Sowing Prep.	Thinn. Cult.	Operator	Hoe Labour
MULTI System						
CHECK	6.8	-	11.7	8.2	27.0	77.8
Herb. Means	-	6.8	7.2	8.2	22.2	38.7
Trf. 0.8	-	6.8	7.0	8.2	22.0	39.4
Trf. 1.2	-	6.8	8.0	8.2	23.0	49.7
din. 0.4	-	6.8	6.7	8.2	21.7	27.1
System Means	6.8		8.3	8.2	23.4	48.5
SINGLE system						
CHECK	13.6	-	9.3	19.4	84.6	131.0
Herb. means	13.6	8.0	9.3	9.1	80.0	42.5
trf. 0.8	13.6	8.0	9.3	9.0	79.8	47.3
trf. 1.2	13.6	8.0	9.3	9.6	81.0	54.1
din. 0.4	13.6	8.0	9.3	8.7	79.2	26.0
Systems means	19.6		9.3	11.6	81.0	64.6

Table H.III/3/2.4 Crop totals and profitability

Treatment	Cotton shoot wt t/ha	Seed cotton kg/ha	Machine total hr/ha	Labour total hr/ha	Production costs	Net profit.
MULTI System						
CHECK	1.75	502	40.6	256	109.06	41.53
Herb. means	1.96	623	33.1	189	98.60	88.30
trif. 0.8	1.97	721	34.9	252	118.95	97.35
trif. 1.2	2.16	613	36.6	209	107.91	75.99
din. 0.8	1.83	633	32.3	181	90.31	99.59
trif. 0.8 + MSMA	2.19	546	32.3	204	102.51	61.29
trif. 1.2 + MSMA	1.97	548	30.5	126	81.15	83.25
din. 0.4 + MSMA	1.67	675	32.2	150	80.91	121.59
System means	1.91	591	35.0	206	102.08	75.22
SINGLE System						
CHECK	1.65	642	50.0	414	173.06	19.54
Herb. means	1.99	526	43.9	324	150.61	7.19
trif. 0.8	2.13	607	45.4	313	144.32	37.78
trif. 1.2	1.63	518	46.4	363	170.40	15.00
din. 0.4	2.35	503	42.5	330	150.91	0.31
trif. 0.8 + MSMA	2.22	556	42.9	324	151.54	15.26
trif. 1.2 + MSMA	1.72	452	45.0	354	169.69	34.09
din. 0.4 + MSMA	1.87	523	41.2	326	152.22	4.68
System means	1.92	556	45.4	351	156.22	10.58

Profitability was low in this experiment primarily as a result of the low yield. This was certainly due to incorrect insecticidal spraying (see general crop agronomy). The better profitability of the MULTI system was undoubtedly due mainly to the lower hoe labour demand in August and September.

The generally low production cost of either straddle row system compares favourably with the known production costs of growing cotton with a ridger as the only cultivation tool.

Sub-Project H.III/3/2. vi. Weed Control with animal power in a millet-sorghum mixture 1979.

A comparison of cultivation techniques:

In 1979, the STRAD toolbar was also commercially available in a cheaper version fitted with locally made 'picker' time rotors. The modifications to the SRRW prototype were not complete at the beginning of the season and this machine was therefore not tested in 1979.

Table H.III/3/2.5 Specification of tillage system, 1979.

Operations	Systems		
	STRAD	PICKSTRAD	EMCOT
'Deep' primary cultivation.	18/5/79 Rotor angle 25°	26/5/79 Rotor angle 30°	-
Sowing and minimum tillage	28/5/79 by sowing tube during seedridge preparation.	29/6/79	30/5/79 by sowing tube in farrow behind ridger.
First ridge splitting and fertilizer sidebanding.			18/6/79 without mould boards.
First cultivations and fertilizer side banding	25/6/79	22/6/79	-
First hoe weeding and thinning	3/7/79	3/7/79	2/7/79

Design: 5 cultivation treatments applied to 20 main plots.

Plot size: Main = ha/78.00

Treatments:

PICKSTRAD VS STRAD rotors

X

Deep seedridge cultivation VS MINIMUM.

+

EMCOT furrow sowing fb ridge splitting.

Bassal fertilizer 112.5 kg of 20-20-0 /ha

Results:

Crop establishment inputs. (Table H.III/3/2.6).

The heavy clay loam soil at Samaru cannot be split by the EMCOT ridger to prepare cereal seedridges at the beginning of the rains. There is therefore no established farming system using this equipment near Samaru, but the furrow sowing technique developed in 1977 by mounting a sowing tube behind the riger was used again in 1979. This operation compared very well with the

MULTI system used in 1978 and required only 15.3 compared to 27.0 man hr/ha. Both systems required many fewer man hours than the hand sowing normally used by the traditional hoe farmers of the area. The STRAD operation with the integral sowing tube was a little slower (8.5 compared with 7.6 hr/ha) but was a one-man operation.

Table H.III/3/2.6. Man and machine hours required to establish a Millet Sorghum mixture by animal power.

Cultivation	Primary cult. hr/ha	Crop sowing man hr/ha	1st cult. man hr/ha	1st hoeing man hr/ha	Total man hr/ha	Total machine hr/ha
STRAD DEEP	6.29	8.56	4.23	54.29	73.37	19.08
STRAD MIN	-	8.46	4.20	76.75	89.40	12.66
PICK DEEP	3.13	8.51	6.23	72.74	87.48	14.74
PICK MIN	-	8.54	7.31 (ridges splitting)	81.70	100.68	18.48
(2 man operations)	-	15.29	15.66	125.36	156.43	15.48
	+	.091	+ .079	+ .497	+ 26.152	

The effect of extra 'deep' seed ridge primary cultivation in improving early post-emergent weed control and reducing man-hours for 'down the row' thinning can be clearly seen in the table. There were overall reductions of 16 and 13 man hours/ha with the Lilleston and Picker-time rotors respectively. There were also marked improvements in crop vigour with this technique. All the STRAD treatments used much less labour than the improved EMCOT which itself used for fewer man-hours than the established techniques traditionally used with the EMCOT in the light textured soil areas where animal power farming is now established.

The commercial availability of high clearance straddle row rotory cultivators has therefore made it technically possible to animal power cultivation to heavy land area where it has so far not been widely adopted.

Sub-Project H.III/3/5 vii. Striga Ecological studies 1977 - 78.

R. A. Mansfield.

Observations during 1977 and 1979 (see tables H.III/3/5.1) showed that 'gero' (day length neutral) pennisetum millet is regularly parasitised by Striga hermonthica in the Sudan ecological zone. The 'dry season' harvest period of gero in this zone supports the production of viable striga seed and thus maintains a district 'gero-sensitive' race of striga in this zone. Gero harvested during the wet season in the Guinea zone, does not support the production of viable striga seed and therefore the 'gero-sensitive' race of striga is either not present or is greatly attenuated. The recommended 'ex-Borno' gero cultivar is almost completely immune to striga attack at Samaru.

The probable reasons for this observed zonal variation are:-

1. Soil temperature

S. hermonthica probably requires a diurnal peak temperature between 25-30°C to permit germination in moist soil. (Parker, 1965). These temperatures are not reached while the soil is at field capacity during July - August in the Guinea zone.

3. Rainfall distributions

In contrast to the Northern Guinea zone, rainfall is lighter and less frequent in the Sudan zone so that the surface soil frequently dries and moistens during the rains. This maintains the striga seed in a fit state to germinate whenever stimulated by the promimity of a host root. In the Northern Guinea zone, striga germination occurs during a comparatively short period when the soil dries at the end of the rains.

These factors account for the frequent observation that vegetative striga occurs on gero at heading and on sorghum before heading in the Sudan zone. Even if early striga emergence does occur on sorghum inthe Northern Guinea zone most of the emerged striga cannot survive the pathogenic attack which develops in the continuously wet soil and microclimate during the rainfall peak.

There are a number of control implications resulting from these observations :-

4. Breeding programmes for tolerance/resistance in gero are only required for the Sudan zone.

5. The introduction of resistant varieties of either sorghum only or gero only will not stop striga seed production in the Sudan zone. The new resistant variety will be challenged continuously by the seed produced on 'other' crops. It is therefore essetial to combine the introduction of a new variety with integrated control measures to prevent striga seed production at any stage of the cropping system. These should include control of emerged striga by foliar herbicides, the control of alternative grass weed hosts and stubble clearing to prevent post-harvest striga seed production on cereal crop ratoons.

6. There should be little striga attack in Sudan zone irrigation schemes because these inevitably tend to be over-irrigated but if an attack does develop in a particular schemes, a useful control measure would be to continue irrigation through the harvest to maintain the soil moisture contents above the threshold for striga germination.

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3. Vallance, K.B. (1950). Studies on the germination of the seeds of Striga hermonthica I. the influence of moisture treatment, stimulant dilution and after-ripening on germination. ANN. Bot., Vol. 14 pp 347-63.

2. Soil moisture

Striga seed can be pre-conditioned to germinate effectively during the wetting cycle in the Northern Guinea zone providing that the rainfall is light during June (Ogborn, 1971) but inmany seasons the surface soil remains saturated throughout June, July and August. It is probably that the striga seeds in the soil become 'wet-dormant' (Vallance, 1950) during this period and cannot germinate even if the soil termperature rises temperarily.

Table H.III/3/5.1. Striga host preference, 1977 - 8.

Km from Samaru	Location	Date	Cereal Crops present	Crops attacked by Striga
North west of Samaru to Illela.				
0	Samaru	July 78	Gero - Sorghum	Sorghum only
5	Shika	Nov. 77	" "	" "
72	Funtua	Nov. 77	" "	" "
179	Gusau	Aug. 78	" "	" "
	Magaji	Nov. 77	" "	" "
241	Majinghi	Aug. 78	" "	" "
274*	Talata Mafara	Aug. 78	" "	Gero + Sorghu
306	Talata Mafara	Nov. 77	" "	" + "
406	Sokoto	Nov. 77	" "	" + Sorghu
488	Illela	Nov. 77	" "	" only
North east of Samaru to Daura				
10	Samaru	July. 78	Gero - Sorghum	Sorghum only
30	Makarfi	Jul. 78	" "	" "
46	Soka	Jul. 78	" "	Gero + Sorghum.
72	Dangora	Jul. 78	" "	Sorghum only
72*	Dangora	Oct. 78	Sole gero	Gero
104	Kadawa	Oct. 77	Gero - Sorghum	Sorghum only
124	Kadawa	Oct. 77	Gero - Sorghum	Gero + Sorghum
154	Kano FC	Aug. 78	Gero - Sorghum	Sorghum only
	Kano FC	Aug. 78	Sole gero	not attacked
211	Dambata	Oct. 77	Gero - Sorghum	Gero + Sorghum
	Dambata	Aug. 78	Gero - Sorghum	Sorghum only
	Dambata	Oct. 77	Gero - Sorghum	Gero + Sorghum
	Dambata	Oct. 77	Gero - Sorghum	Gero + Sorghum
230 (approx)	Bakura jnct. + 50 kg to Babuba	Aug. 78	" "	" "
257	Kazaure	Aug. 78	" "	Sorghum only
	Kazaure	Sep. 78	" "	Gero + Sorghum
277	Fago	Sep. 78	" "	" "
	Fago	Nov. 77	" "	" "
294	Daura	Jul. 78	" "	" "
	Daura	Jul. 78	Sole gero	Gero
	Daura	Oct. 77	Gero - Sorghum	Gero + Sorghum.

*. Approximate position of the Northern Guinea-Sudan zonal boundary.

H.III/3/5. vii. Striga control by using striga germinators

Effect of time of Application of Germinators on Striga control in Maize at Mokwa (S. Guinea zone)

Objective : To find, for Mokwa, the best rate of GR45 and the best time of application for striga control in Maize.

Site : National Grain Production C.-Mokwa.

Method : An incomplete block design with ha/314 per net plot. (4 reps, 3 plots per sub block).

Treatments (Per block)

1-0.1 kg/ha GR45 at 4 days preplant
2-0.2 " " " "
3-0.4 " " " "
4-0.1 kg/ha GR45 at 2 days preplant
5-0.2 " " " "
6-0.4 " " " "
7-solvent check
8-No solvent check
9-ethepon 1.6 kg/ha at 2 days preplant.

Basal treatments -'supa'-500kg/ha (boronated)
'C.A.E.'-500-400kg/ha (28%N)
150-200 kg/ha applied 1 week post plant.
150-200 kg/ha applied 2 weeks post plant.
Butylate 6.4 kg/ha (78% e.c) incorporated at planting.

All treatments incorporated with Lilliston cultivator.

Crop: Maize farz 27 in 3 ft rows, 9 inch spacing
5 rows/gross plot, 3 rows/net. (Net plots 2.75 mx11.6 m)

Field Operations

9/5/79	4 days preplant treatments of GR 45 applied and incorporated
11/5/78	2 day preplant treatments of GR 45 applied and incorporated
12/5/78	Ethepon and butylate applied and incorporated
13/5/78	Maize and 'supa' drilled, mechanically.
23/5/78	First application of C.A.N.
1/6/78	Second application of C.A.N.
7/6/78	Transplanting and thinning
22/6/78	Hand weeding.
10/7/78	First flowering striga seen
19/8/78	First ripe mature striga seen.
28/8/78	Harvesting of Maize.

Table H.III/3/5.3. Effect of time of application of germinator on grain weight of maize (kg/ha) at harvest

	(TREATMENT)		
Germinator rate kg/ha	2 days pr -plant	4 days pre-plant	Mean
0.1 GR 45	1763(.050)	2880	2323
0.2 GR 45	1973(.094)	2745	2361
0.4 GR 45	2893	2798	2845
Mean	2210	1808	2845
Ethepon 1.6	3311 (.151)		
CHECK	2762		

(values in brackets show significance of 't' for treatment versus check or for 2 averages)

Table H.III/3/5.4. Effect of time of application of germinators on nature striga (1000s/ha) at harvest

(Treatment means)

Germinator rate kg/ha	2 days pre-plant	4 days pre-plant	Mean
0.1 GR 45	4.4	4.6	4.5
0.2 GR 45	7.6 (.039)	5.9 (.204)	6.7 (.054)
0.4 GR 45	2.9	1.4 (.86)	2.2
Means	5.0	4.0	
Ethepon 1.6	5.9 (.141)		
CHECK	3.9		

(values in brackets same as table H.III/3/5.3)

Table H.III/3/5.5. Effect of germinator and time of application on total striga (1000s/ha at harvest.

(Treatment means)

Germinator rate kg/ha	2 days pre-plant	4 days pre-plant	mean
0.1 GR 45	21.0 (.051)	31.7 (.083)	26.4
0.2 GR 45	32.5 (.056)	35.1 (.026)	33.8 (.014)
0.4 GR 45	18.3 (.012)	20.3 (.024)	19.3 (.006)
Means	24.0	29.0	
Ethepon 1.6	24.0 (.174)		
CHECK	26.9		

(values in brackets show significance of 't' for treatment vs check or for two averages)

Table H.III/3/5.6. Effect of germinators and time of application on total shoot weight (kg/ha) at harvest)

Germinator rate kg/ha	2 days pre-plant	4 days pre-plant	Means
0.1 GR 45	4665 (.060)	5902	5284
0.2 GR 45	5209 (.114)	7375	6292
0.4 GR 45	7252	7532	7392
Means	5709	6936	
Ethepon 1.6	9420 (.034)		
CHECK	6940		

(values in brackets show signifinance of 't' for treatment vs check).

Effect of time of application of germinators on striga control in maize sorghum and millet at Keza (Sudan Zone)

All crops failed due to late planting caused by late arrival of chemicals. Bioassays for resisual striga are now being done at Samaru. No striga emerged on the experimental site in contrast to surrounding fields. This might have been caused by the high N level and basal linuron herbicide applied to all treatments.

The interaction of germinators and herbicides on striga control in maize at Mokwa (Southern guinea zone)

Objective : To find, for Mokwa, the best combination of herbicide and germinator at Mokwa (S. Guinea) for striga control in maize.

Site : National Grains Production Co. Mokwa.

Method : A split plot experiment with net plots of ha/314.

Main plots = Butylate 6.4 kg/ha vs no butylate.

Sub - plots = 0.0 kg/ha GR 45
0.1 "
0.2 "
0.4 "
and ethepon 1.6 kg/ha

(4 reps, 2 main plots per block, 5 sub-plots per main plot)

Basal treatments -'SUPA' 500 kg/ha (boronated)
'CAN' 28% N, 500-400 kg/ha
150-200 kg/ha applied at planting.
150-200 kg/ha applied at 1 week later.
-all treatments incorporated with a Lilliston cultivator.

Crop : Maize Farz 27 in 3 ft rows.
5 per gross, 3 per net plot
9 inch spacing between stands.

Field Operations

11/5/78	Gr 45 treatments applied.
12/5/78	Butylate and ethepon applied and incorporated.
13/5/78-23/5	Maize planted, fertiliser applied.
1/6/78	Application of C.A.N. and thinning
7/6/78	Hand weeding
10/7/78	First flowering of striga
19/8/78	First ripe mature striga
28/8/78	Maize harvested.

Table H.III/3/5.7. Interaction of butylate and germinators on grain weight of maize (kg/ha) at harvest

Germinator rate kg/ha	Butylate 6.4 kg/ha	No butylate	Means
0.0 GR 45	841	938	890
0.1 "	1493	1085	1289
0.2 "	551	868	710
0.4 "	1310	847	929
Ethepon 1.6	1344	846	1095
Means	1108	857	

Table H.III/3/5.8. Interaction of butylate and germinators on mature striga count (1000s/ha) at harvest 1978.

(Treatment means)

Germinator rate kg/ha	Butylate 6.4 kg/ha	No butylate	Means
0.0 GR 45	7.0	4.9	6.0
0.1 "	7.9	6.1	7.0
0.2 "	8.0	4.6	6.3
0.4 "	5.3	6.6	5.9
Ethepon 1.6	3.1	6.4	4.7
Means	6.2	5.7	

(Treatment means)

Germinator rate kg/ha	Butylate 6.4 kg/ha	No butylate	Means
0.0 GR 45	4426	5315	4870
0.1 "	6684 (.0141)	5741	6213
0.2 "	3666	4293	3980
0.4 GR 45	6517	3238	4878
Ethepon 1.6	6177	4569	5378
Means	5494	4631	

Table H.III/3/5.10. Interaction of butylate and germinators on total striga at harvest (1000s/ha)

(treatment means)

Germinator rate kg/ha	Butylate 6.4 kg/ha	No butylate	Means
0.0 GR 45	16.6	13.5	15.1
0.1 "	20.5	15.9	18.2
0.2 "	16.8	13.0	14.9
0.4 "	14.2	18.1	16.1
Ethepon 1.6	14.2	18.1	16.1
Means	16.0	15.6	

Results and discussion

Time of application

Reanalysis of the 1977 Samaru experiment after the 1978 experiments had started showing that striga germinators were stable for several weeks in acid Nigerian Savanna soils. Consequently the contrast of 2 versus 4 days pre-plant treatments could not be expected to produce large differences. Nevertheless, 0.1 kg ai/ha of GR 45 in the presence of butylate produced a detectable reduction in striga emergence at 2 days pre-plant and a comparable increase at 4 days. (Table 5.5). The identical treatment in the herbicide interaction experiment produced a small incfease in emergence (table 5.10). This discrepancy may be explicable in terms of the different levels of striga infestation on the experimental sites. The CHECK treatment in table 5.5 had a total emergence of 26.8 thousand striga of which 15% matured at harvest whereas the equivalent treatment in table 5.10 had a total emergence of only 16.6 thousand but over 45% matured at harvest.

0.2 units reduced yields when applied 2 days pre-plant in all treatments 0.4 units markedly reduced striga emergence and did not reduce grain yields in the presence of butylate. It is now clear however, that all desages of germinator should be applied much earlier than in these experiments.

Herbicide germinator interactions

There were no larger economic reponses to germinator treatment in the absence of butylate but in the presence of butylate ethepon gave large and profitable responses in both experiments.

The break-even value of ethepon in these experiments was ₦95.16 and ₦103.86 respectively per kg ai. This chemical is commercially available in Nigeria at a current price of ₦21/kg a.i.* .

GR 45 also gave large increase in grain yield. The results how that it decomposes only slowly in moist soil, current experiments in 1979 are designed to evaluate it, when applied pre-plant without incorporation or when applied post-harvest in the dry season. These are the only modes of application practicable for the hoe farmer. It appears that ethepon which must be incorporation has little potential for use by hoe farmers.

* As 'Ether' (48% ec) from National Oil and Chemical Marketing Company.

H.III/3/6.1. Chemical control of imperata

S. T. O. IAGOKE

EFFECT OF VOLUME OF APPLICATION OF GLYPHOSATE AND POST- SPRAYING SLASHING ON SPEARGRASS

Site : Mokwa

Glyphosate was either applied in very low volume (20 L of water per hectare) at the rates of 0.5, 0.75, 1.00 and 1.50 kg ae per hectare with additional wetter (Agral '90' at 2% of spray liquid), or in high volume (250 L / hectare with 0.4% additional wetter). Spraying were done on 7/12/77. As shown on Table H.III/3/6.1, some of the plots were slashed on 3/1/78. All applications were done on 60 - 75 cm speargrass regrowth. All treatments were arranged in a split - plot design and replicated two times.

Results and discussion

Effect of various treatments on speargrass regrowth at about 18 weeks after spraying is shoen in table. H.III/3/6.1. No difinite advantage can be attributed to post-spraying slashing in this trial. With slashing, relative performance of high volume was actually reduced; 0.5 kg ae/ha glyphosate in VLV was as effective as 3 kg ae/ha in HV in the slashed plots. 1.0 and 1.50 kg ae glyphosate in VLV also gave better speargrass control on the unslashed plots. Very low volume application of glyphosate was still better in this trial. The activities of 0.5, 0.75 and 1.0 kg ae/ha glyphosate were increased 3 - and 4 - fold. All herbicides however, controlled speargrass to varying degrees - 58% to 99%.

Glyphosate at the rates of 0.75 and 1.0 kg ae/ha in VLV, applied in the early part of the dry season, can now be recommended conveniently for use on speargrass, even without an additional dry season cultivation. This will cost between ₦30 and ₦42 per hectare to apply. There are various advantages viz: application in the dry season which allows enough time for additional control measure in case of any regrowth, the non-residual effect on crops, and the ease of application in very low volume which lend support to its recommendation. It is also commercially available in Nigeria*

Table H.III/3/6.1. EFFECT OF VOLUME OF APPLICATION OF GLYPHOSATE AND POST-SPRAYING SLASHING ON SPEARGRASS REGROWTH

Herbicide applied 7/12/77	Speargrass score (0 - 10) at 18 weeks after spraying		
	Slashed on 3/1/78	Unslashed	Means
Glyphosate 0.5 in VLV	1.50	2.00	1.750
" 0.75 "	1.50	1.50	1.500
" 1.0 "	1.50	0.50	1.000
" 1.5 "	2.25	1.00	1.625
" 1.5 in HV	3.50	5.00	4.250
" 2.0 "	2.75	2.75	2.[illegible]75
" 4.0 "	1.25	0.50	0.875
Unsprayed control	8.75	10.00	9.375
Means	2.722	2,667	

Effect of cultivation and time of application on the activity of glyphosate on speargrass

Site : Mokwa.

Glyphosate was applied on speargrass at 4 dates (December through February) at 0.5, 0.75 and 1 kg ae/ha in 20 L H20 of water per hectare, and cultivated with 2 - bottom furrow disc plough at 3 weeks after each application 2% Agral added to the spray solution of glyphosate. All the plots were disc harrowed before sorghum was sown in June 1978.

* As 'Roundup' from National Oil and Chemical Marketing Company.

Results and discussion

Results are shown on table H.III/3/6.2. Irrespective of time of application or herbicide treatment, cultivation with double bottom furrow disc, reduced speargrass dry matter production considerably in this trial. Reduction ranged between 88 and 100 percent-mean of time and herbicide treatments. With the cultivation done in the first week of March, speargrass was completely eradicated on the unsprayed plots. Conversely, the highest speargrass production occurred on the plots sprayed at this time when no cultivation was done. Speargrass control increased with increase in the dosage of glyphosate.

Cultivation in the dry season resulted in increased grain yield in all treatments. Increase in sorghum grainyield ranged from 4 to 24%.

Cultivation irrespective of time of post-spraying cultivation enhanced the activity of the lowest rate (0.5 kg ae/ha) on speargrass, although the effect was differential. It was most enhanced on the plots, sprayed on 10/2/78 and cultivated on 3/3/78. The activities of higher rates were definitely enhanced when applied in late December, January and February. This effect on 0.75 kg ae/ha might be due to drier conditions. Similar reasons might be used to explain the enhancement of the performance of 1 kg ae/ha glyphosate on speargrass by cultivation when applied in February.

The above results suggest that application of glyphosate in the early part of the dry season would be most suitable. Additional post spraying cultivation to give a complete control of speargrass might be required, especially with the low rate. However, where the nature of the terrain prevents the use of tractor mounted implements, a higher rate 0.75-1 ae/ha should be applied in December in very low volume (20L/ha) with an additional wetter Agral '90' at 2% VLV.

Table H.III/3/6.2. Effect of speargrass cultivation on sorghum grain yield (kg/ha)

Dates of Spraying	Dates of Cultivation	Cultivation at 3 weeks after spraying	No cultivation after spraying	Means
8/12/77	29/12/77	3077	2523	2800
29/12/77	20/1/78	3313	2811	3062
20/1/78	10/2/78	2938	2832	2882
10/2/78	3/3/78	3078	2487	2783
Means		3101	2663	

Table H.III/3/6.3. Effect of time of glyphosate application and post spraying cultivation on speargrass shoot wt kg/ha

Dates of Spraying	Dates of cultivation	Glyphosate at 0.5 kg *	Glyphosate at 0.75 kg	Glyphosate at 1.0 kg	Unsprayed control	Means
8/12/77	29/12/77	27. 5	8. 0	24. 0	72. 8	33.08
8/12/77	-	366. 7	0. 0	28. 4	1118. 9	378.50
Means		197.10	4.00	26.20	595.85	205.79
29/12/77	20/1/78	44. 4	0.0	0.0	26. 0	17.75
29/12/77	-	386. 3	75. 5	95. 9	1092. 2	412.48
Means		215.35	37.75	47.95	559.40	215.12
20/1/78	10/2/78	51. 5	97. 7	0.0	0.0	74.60
20/1/78	-	206. 9	108. 3	0.0	925. 3	310.13
Means		129.20	103.00	0.0	462.65	192.37
10/2/78	3/3/78	0.0	0.0	0.0	0.0	0.0
1-/2/78	-	518. 5	470. 6	88. 8	1133. 1	802.75
Means		759.25	235.30	44.40	566.55	401.38

* kg ae/ha.

H.III/3/6. iii Imperata eradication by dry season cultivation

S. T. O. LAGOKE

Effect of time of cultivation on speargrass

Site : Mokwa.

Speargrass infested stips were cultivated with single bottom furrow disc on 6/12/77, 5/1/78 respectively, using 3rd low gear and maintaining tractor at 1600 rpm. Regrowth were sprayed on 20/4/78 before planting was done.

Results and discussion

Pre-application score was done until 20/4/78 in order to determine the effect of time of cultivation on speargrass. Table H.III/3/6.4 shows the percentage speargrass regrowth on 20/4/78. The least regrowth ocourred on the plots ploughed in December, with speargrass regrowth increasing as the time of cultivation was delayed in the dry season. This might be due to less penetration as the soil dried, and rhizome dessication occurred for a shorter period as the time of cultivation was delayed.

Table H.III/3/6.4. Effect of time of cultivation on speargrass regrowth.

Date of cultivation	% speargrass regrowth.
6/12/77	5.5%
5/1/78	16.0%
76/2/78	30.0%

Effect of length of top link and number of discs and time of disc ploughing on speargrass

Site : Mokwa

Speargrass-infested are was cultivated at different times of the dry season (9/12/77, 9/1/78 and 9/2/78), using either a single bottom or a double-furrow disc plough. The lengths of the top links were also varied, for the single-bottom-furrow disc plough 60 cm, 63 cm and 65 cm were used while 65 cm 67 cm and 69 were used for the double bottom furrow disc plough. All the treatments were arranged in a randomized complete block design and replicated two times. Plot sizes were 5 cm wide and 10 m long. During cultivation, tractor was on the third low gear and maintained on 1600 rpm. Speed was approximately 6 m/sec.

Results

Table H.III/3/6.5 shows the effect of the different treatments on speargrass regrowth at 10 weeks after the last cultivation.

Speargrass regrowth was lowest on the plots ploughed with single bottom furrow disco in early December, resulting in 75.7% control at 18 weeks after cultivation. This was best achieved with top link length of 63 cm which resulted in 85% control. With the December cultivation, the single-bottom-furrow-disc plough was twice as effective as the double bottom furrow disc plough. However, as the time of cultivation was delayed the differences in activity of both types of discs reduced. With the double bottom furrow disc plough, the best performance occurred in December when 69 cm top link length was used.

Discussion

From the above result, it is clear that speargrass control is best achieved with a single-bottom-furrow disc plough. Provided the soil is not moist enough for rhizome regeneration, early cultivation is advantageous to help the disc penetration of the top link length as manifested in the result of this trial, for effective and stable penetration. Since in a trial conducted on another site on this station, complete control was even achieved when disc harrowing also followed the use of double bottom furrow disc, it is important that the appropriate time of cultivation and top link length be known.

A double-bottom furrow disc might be effective in areas where the depth of penetration of the rhizome is minimal. This might also be a function of the soil type. Where this is possible, effective control can be achieved with early dry season cultivation using about 69cm top link length for effective and stable penetration.

Table H.III/3/6.5. Speargrass % regrowth as effected by the different treatments

SING	SINGLE DISC PLOUGH			
Top link length Date of cultivation	60 cm	63 cm	65cm	Mean
9/12/77	35	15	23	24.3
9/1/78	23	33	45	33.7
9/2/78	61	38	35	44.7
Mean	39.7	29.0	34.3	

	DOUBLE DISC PLOUGH			
Top link length Date of cultivation	65 cm	67 cm	69 cm	Mean
9/12/77	48	58	45	50.3
9/1/78	65	73	50	63.7
9/2/78	100	63	50	71.0
Mean	71.0	64.7	48.3	

PN-AAQ-053
ISN=34754

REPORT TO THE BOARD OF GOVERNORS ON THE INSTITUTE'S WORK

1977–1978

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FARM SYSTEMS AND INTERCROPPING PROGRAMME

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EXPERIMENTAL CROPPING SYSTEMS AND WEED CONTROL
I.A.R. PROGRAMME "H"

As in previous years the work under this committee will be reported under the three heads; intercropping, rotations and fallows, and weed control. Additionally, this year, individual projects are reported under the new IAR programme coding and, where relevant, IAR trials are reported first, followed by State trials under each heading.

Sub-programme H.I. Intercropping
Project H.I./2: Other cultural practices and management
Sub-project H.I./2/1

To determine intercropping practices in different ecological zones of the Northern States, and to explore the strategy of the practices. (R. Palmer-Jones; E.F.I. Baker).

One of the difficulties of working with crop mixtures has been to determine reasons why particular mixtures are used. It has been relatively easy to show that some mixtures give greater yields than equivalent sole crops, but such work has been based upon fixed ratios and, often, fixed sowing dates of crops in the mixtures. Farmers, however, do not adhere rigidly to patterns but vary sowing dates and ratios of crops in mixtures, and may even substitute different crops depending upon their assessment of economic and climatic factors. It is very difficult, if not impossible, to include all contingencies in formal experiments but this problem can be simplified if we knew what farmers did in particular years and areas. What, for example, was the sequence of operations of farmer A in one year, did he modify the sequence, and if he did, how did he modify the sequence in different years; how did this compare with farmer B? I do not believe we can ask the farmer to explain his strategy but I do believe that given enough examples we can deduce some common reasons, and thence to identify constraints. Our approach may be by questionnaire, informal interview, or a combination of both, and I hope States will assist by making it possible for us to contact ordinary farmers.

Sub-project H.I./2/2

To determine returns from intercropping systems when compared with equivalent sole crop systems, and to investigate possible improvements. (E.F.I. Baker)

(i). Gicoi intercropping with groundnuts (E.F.I. Baker)

Experiments comparing sole crop groundnuts with groundnuts intercropped gicci with cereals have been done at IAR since 1974. The first phase of these experiments has been completed and results are summarised below.

Table H.I./1
Yield of groundnuts as unshelled nuts in kg ha^{-1}

	1974	1975	1976	Mean
Sole groundnut	3219	837	3466	2507
Sole groundnuts, close gaps	3138	797	3002	2312
Sole groundnuts, wide gaps	3381	976	3157	2505
With maize, close	2228	704	2939	1957
With maize, wide	2629	904	3293	2275
With millet, close	2447	708	3621	2259
With millet, wide	2323	673	3130	2042
With sorghum, close	2609	668	1811	1696
With sorghum, wide	2515	767	2302	1861
With maize/millet, close	2254	667	3048	1989
With maize/millet, wide	2974	737	2829	2180
With maize/sorghum, close	1954	638	2256	1616
With maize/sorghum, wide	2695	803	2575	2057
With millet/sorghum, close	2257	603	2693	1851
With millet/sorghum, wide	2961	733	3030	2241
With maize/millet/sorghum, close	2175	701	2866	1914
With maize/millet/sorghum, wide	2316	862	2693	1957

Sowing sole groundnuts with close gaps (every 1.37m.) or wide gaps (every 2.78m.) did not significantly affect groundnut yields. Thus mean sole groundnut yield, over all years, can be taken as 2441 kg. ha^{-1}. Sowing cereals in these gaps significantly reduced groundnut yields, although only in 1976 did one cereal, sorghum, reduce yields more than the other cereals.

Thus, mean yield of groundnut, over all years, when mixed with cereal was 1992 kg. ha^{-1}, a loss of 18.4%. However, sowing cereals at close spacing reduced a groundnut yields to 1898 kg. ha^{-1}, a loss of 22.2%, compared with sowing cereals at wide spacing; this reduced groundnut yields to 2077 kg. ha^{-1}, a loss of 14.9%.

Using the gicci system, with cereals sown at the same time as groundnut, does reduce groundnut yields significantly. However, this reduction in yield, and value, does not take into account yields, and value of yields, of the cereals. Table 2 gives mean cereal yields obtained over the three years of the experiments.

Table H.I./2

Mean yields of cereals (1974-76) from gicci groundnuts, in kg. grain ha^{-1}

	Maize	Millet	Sorghum
Maize, close	1155		
Maize, wide	622		
Millet, close		1209	
Millet, wide		643	
Sorghum, close			1619
Sorghum, wide			888
Maize/millet, close	421	874	
Maize/millet, wide	311	362	
Maize/sorghum, close	514		914
Maize/sorghum, wide	196		364
Millet/sorghum, close		588	796
Millet/sorghum, wide		343	340
Maize/millet/sorghum, close	350	838	515
Maize/millet/sorghum, wide	204	392	213

If the values of the groundnut yields are added to the value of the cereal yields, and compared with the value of sole groundnut, a clear picture of the superior income from the gicci system over sole crop groundnut emerges. Table H.I./3 gives gross cash returns using cash values for each crop that obtained in each year. Value of groundnut is .70 of the Marketing Board price for shelled nuts in each year.

Underlined in the table are those gross returns which were less than those from sole crop groundnut, although over all years there was never a return less than sole crop groundnut. Of the three years underlined, only one gave a significant decrease of return, the other two were not different. Thus, since there were 42 opportunities. (14 mixture x 3 years), the farmer can expect a loss once in 42, a negligible risk.

Over all years the gicci system, with cereals sown at the same time as groundnut, significantly increased cash return, and averaged 27.7% gain. This average gain can be increased to 39.4% if the cereals are sown at close spacing. The average gain from using one cereal at close spacing was 37.8%; from using mixtures of two cereals at close spacing was 36.2%; and the average gain from using all three cereals in the mixture was 53.7%.

Table H.I./3

Gross returns in Naira for sole groundnut and groundnut grown under the gicci system with cereals

	1974	1975	1976	Mean
Sole groundnut	341	152	562	352
With maize, close	471	209	570	416
With maize, wide	410	199	603	404
With millet, close	649	153	808	536
With millet, wide	425	129	668	407
With sorghum, close	413	273	823	503
With sorghum, wide	345	220	669	411
With maize/millet, close	632	159	680	490
With maize/millet, wide	514	159	555	409
With maize/sorghum, close	365	240	751	452
With maize/sorghum, wide	337	206	577	373
With millet/sorghum, close	503	200	784	496
With millet/sorghum, wide	451	174	673	433
With maize/millet/sorghum, close	639	205	781	541
With maize/millet/sorghum, wide	424	199	609	411

However, since in these experiments both cereals and groundnut were sown at the same time, when the rains had established, and there was no need to sow cereals at wide spacing, it is relevant to ask if the farmer would gain more by sowing part of the total area to sole groundnut and part to sole cereals. In these experiments the cereals, at close spacing, occupied 16.7% of the land. Thus to sow the same area to sole crops 83.3% must be to groundnut and 16.7% to cereals. Table H.I./4 gives gross cash returns from growing the same area to sole crops for the three years of the experiments. Groundnut yields are those from the sole crop in the experiments. Since sole cereals were not used good average yields for millet (1500 kg.), sorghum (2500 kg.), and maize (5000 kg.) were used for each year.

Table H.I./4

Estimated gross cash returns in Naira from equivalent areas of sole crops

Crops	1974	1975	1976	Mean
Groundnut, maize	426	237	725	463
Groudnut, millet	380	191	606	392
Groundnut, sorghum	388	199	656	414
Groundnut, maize millet	402	213	666	427
Groundnut, maize, sorghum	407	218	690	438
Groundnut, millet, sorghum	385	196	631	404
Groundnut, maize, millet, sorghum	398	209	664	424

Equivalent areas of sole crops always gave greater returns than sole crop groundnuts. However, the best gicci mixtures always gave appreciably greater returns than equivalent sole crops. Further, because cereals, as a sole crop, are sown at a high population, note must be taken of possible total loss due to drought. A factor of negligible importance at the spacings used under the gicci system.

The second series of experiments, designed to follow the farmer's gicci system more closely, by varying sowing date of cereals, was initiated in 1977. Cereals were first sown on 10th May, the day after the first rain at Samaru; the second sowing was on 20th May, and finally cereals and

and groundnuts were sown together on 7th June, when the rains were adjudged established. All cereals were sown in the furrows, at 1.37m. spacing; at the final sowing date superphosphate was applied in the furrows at 250 kg. ha^{-1}, all ridges split and groundnuts sown at .23m spacing along the ridge. Where nitrogen was applied as a treatment to the cereals it was as urea at 17.3g per stand, equivalent to 178 kg. ha^{-1}, and was applied at sowing of the cereal in each case.

Results, in terms of yield and value, are given in the following tables.

Table H.I./5

Yield of maize, as kg. grain, groundnuts, as kg. unshelled nuts and value in Naira ha

Treatment	Date Cereal Sown					
	10 May		20 May		7 June	
	Yield	₦	Yield	₦	Yield	₦
Maize	288	37.4				
Groundnut	1980	346.5				
Maize + N	731	95.0				
Groundnut	850	323.8				
		418.8				
Maize			273	35.5		
Groundnut			2130	372.8		
				408.3		
Maize + N			472	61.4		
Groundnut			1870	327.2		
				388.6		
Maize					105	13.6
Groundnut					2245	392.9
						406.5
Maize + N					380	49.4
Groundnut					2000	350.0
						399.4
SOLE GROUNDNUT					2257	395.0

Table H.I./6

Yield of millet, as kg. grain groundnuts, as kg unshelled nuts, and value in Naira ha.

Treatment	Date Cereal Sown					
	10 May		20 May		7 June	
	Yield	₦	Yield	₦	Yield	₦
Millet	280	50.4				
Groundnut	1600	280.0				
		330.4				
Millet + N	400	72.0				
Groundnut	1380	241.5				
		313.5				
Millet			515	92.7		
Groundnut			1990	348.3		
				441.0		
Millet + N			527	94.9		
Groundnut			1770	309.8		
				404.7		
Millet					51	9.2
Groundnut					2180	381.5
						390.7
Millet + N					27	4.9
Groundnut					2160	378.0
						382.9
SOLE GROUNDNUT					2257	395.0

Table H.I./7

Yield of sorghum as kg. grain, groundnuts, as kg. unshelled nuts, and value in Naira ha.

Treatment	Late Cereal Sown					
	10 May		20 May		7 June	
	Yield	N	Yield	N	Yield	N
Sorghum	2135	384.3				
Groundnut	745	130.4				
		514.7				
Sorghum + N	2400	432 .0				
Groundnut	870	152 .2				
		484 .2				
Sorghum			1906	343.1		
Groundnut			1200	210.0		
				553.1		
Sorghum + N			2881	518.6		
Groundnut			890	155.8		
				674.4		
Sorghum					1204	216.7
Groundnut					1650	288.8
						505.5
Sorghum + N					1117	201.1
Groundnut					1680	294.0
						495.1
SOLE GROUNDNUT					2257	395.0

The first point to note is the similarity between results from this experiment and those from the earlier series when cereals and groundnuts were sown at the same time. Groundnut yields were reduced an average of 12% due to the presence of cereals, the greatest reduction being found when sorghum was the cereal. However, rainfall in 1977 was the lowest on record for Samaru, the drought at the beginning and middle of the season being drastic. This early drought is reflected by the poor yields for maize and millet, whose shelling percentages were reduced to 40% and 25% respectively. Sorghum, whose grain forms and matures on end of season rainfall, produced an excellent yield.

Although groundnut yields when cereals were sown at the same time differed only slightly from sole crop yields, except where sorghum was the cereal, a very different situation occurred as the cereals were sown earlier. Groundnut yields were reduced an average of 36% when the cereals were sown 4 weeks earlier, the degree of reduction being related to the cereal sown. Mean groundnut yield reduction when maize was sown early was 14%, when millet was the cereal, 33%, and a drastic 66% when sorghum was the cereal. Although difference were rarely significant yields were further reduced when the cereals were fertilised with nitrogen.

The difference between the cereals in their effect on groundnut yields is readily explained. Both maize and millet competed with groundnut during the early part of the season. The extent of the competition depending upon the early vigour of the cereal. Millet, which is very vigorous in early growth and, at the low population sown, tillers profusely, competed more with groundnut than did maize. Maize is less vigorous and does not tiller. The degree of competition lessened as cereal sowing date was delayed and this was reflected in increased groundnut yields. Sorghum, although slow growing early in the season, competed very vigorously with groundnut late in the season during pod fill and maturation, with consequent drastic reductions in groundnut yield.

State trials:

A series of trials were initiated at 17 locations in 1976, and continued in 1977. The locations were:

*Gwarzo	Maigana	Oturkpo
Malam Maduri	Saminaka	Keffi
Gusau	Sabon Birnin Gwari	Wawa
*Talata Mafara	Daura	*Okuta
*Kaura Namoda	Kafinsoli	Mbatie
Bida	Batsori	

(*logbooks not returned from 1976 or 1977).

Each trial consisted of six replicates of six treatments, which were:

A Sole groundnuts

B Groundnuts with sorghum/millet at wide (2.74m) spacing

C " " maize at close (1.37m) spacing

D " " maize /millet at close spacing

E " " maize/sorghum at close spacing

F " " maize/millet/sorghum at close spacing

Three replicates were sprayed with benlate (approx. 3kg. benlate in 380 litres water ha^{-1}), three replicates were not sprayed. Benlate was not available in 1977. Groundnuts were fertilised with superphosphate at 113 kg. ha^{-1}, cereals with 28 gr. N/chalk per stand (225 kg. ha^{-1}).

Groundnut yields, as kg. unshelled nuts and kg. dried haulms, are given in the following tables. Yields from locations marked * are not included in the mean.

Table H.I./8

Yields of unsprayed groundnuts as kg. unshelled nut ha^{-1}

	A	B	C	D	E	F
Batsori	316	266	283	300	233	237
Kafinsoli	1406	1145	1085	884	874	1256
Saminaka	980	1098	987	1105	1105	1193
Daura	906	818	384	884	700	744
Wawa	1396	1547	1273	-	-	-
Maigana	1333	1700	1200	1367	933	767
Maigana 1977	1196	950	844	-	-	-
Gusau	2433	1767	1900	1500	1400	2067
Sabon Birnin Gwari	633	667	550	533	483	567
Bida	1355	1407	1142	1525	1451	1407
Bida 1977	195	139	155	138	121	133
Mbatie	884	729	464	486	354	1002
Keffi	12 67	1467	1167	1300	1333	1200
MEAN	953	913	796	771	690	814

Mean mixed 800 - a loss of 16.0%

Table H.I./9

Yield of sprayed groundnut as kg. unshelled nut ha^{-1}

	A	B	C	D	E	F
Batsori	383	266	466	433	450	366
Kafinsoli	1065	1406	1145	914	522	1266
Saminaka	1540	1208	1687	1164	1422	1238
Daura	1157	825	1031	994	1017	818
Wawa *	-	-	-	2296	2370	2423
Maigan a	1767	1367	1300	1567	2000	1033
Gusau	1900	1867	1667	1767	1933	1767
Sabon Birnin Gwari	767	683	667	700	600	733
Bida	869	442	1204	1149	1746	1657
Mbatie	457	589	435	250	442	508
Keffi*	3717	3100	2467	2833	2583	2017
MEAN	1362	1175	1257	1279	1371	1257

Mean mixed 1049 - a loss of 4.7%

Table H.I./10

Yield of unsprayed dried groundnut haulms in kg ha^{-1}

	A	B	C	D	E	F
Batsori	2533	2300	2267	2133	2200	2267
Kafinsoli	1800	1790	1660	1850	1720	1950
Saminaka	1525	1761	1599	1687	1716	1311
Daura	2320	2247	1731	1842	1621	1400
Wawa *	10947	5641	5500	-	-	-
Gusau	2010	1672	2437	2055	2041	2255
Sabon Birnin Gwari	767	767	833	767	800	1067
Malam Maduri	2291	1952	2092	2144	1960	1761
Bida	2527	2158	2262	2483	2836	2394
Bida 1977	900	569	594	573	840	624
Mbatie	1370	1024	1274	1061	1134	1053
Keffi	950	792	762	725	708	717
MEAN						

Mean mixed - loss of 9.2%

Table H.I./11

Yield of sprayed dried groundnut haulm in kg. ha^{-1}

	A	B	C	D	E	F
Batsori	2500	2417	2217	2200	2267	2433
Kafinsoli	3160	2597	2110	1983	2087	2120
Saminaka	1436	1341	1812	1658	2011	1554
Dauma	2836	3020	2726	2320	2394	1510
Wawa *	-	-	-	7350	3137	7199
Gusau	2136	2276	2521	2026	2166	2291
Sabon Birnin Gwari	1400	1733	1133	1300	1633	1033
Malam Maduri	1702	1657	1901	1820	1348	1488
Bida	2519	2416	2785	3057	3610	2718
Mbatie	1238	1510	1400	1238	1753	1805
Keffi	983	875	875	858	808	825
MEAN	1991	1984	1948	1846	2008	1778

Mean mixed 1913 - a loss of 3.9%

Mean loss of unsprayed groundnuts over all locations when mixed with cereal was 16.0% (compared with 18.0% loss over all years of the IAR trials). If sprayed, the loss reduces to 4.7%. The picture was similar for haulm yields.

Maize failed at 8 locations, millet and sorghum each failed at 7 locations. From the 15 logbooks so far received (13 for 1976, 2 - Bida and Maigana - for 1977).

Mean cereal yields (mean taken over all 15 locations) were:

Unsprayed Maize 159kg; millet 74 kg; sorghum 89 kg.

Sprayed " 116kg; " 38 kg; " 73 kg.

There were many reasons for the failure of cereals, ranging from drought to eaten by rodents or monkeys. Despite having failed at more than half the locations, maize was a promising addition to the other cereals for this system.

It is hoped to continue this series in 1978, but this may only be possible if States provide groundnut seed.

In general summary these trials have shown (when good management is applied, as at IAR) that the system gives greater gross returns than sole cropping. Even at State locations, where management may be poorer than that of farmers, there was no real loss of revenue.

However, the later series of experiment at IAR, where sowing date is included as a variable, shows that the real value of the system is its flexibility. The farmer can sow groundnuts without losing all the cereals he would have sown on that land; he can sow very early cereals and retain the option to grow more cereals, should those early sown do badly, or groundnut if he is satisfied with his early cereals. He has, of course, other combinations, depending upon his early cereals and estimated selling prices of the various crops concerned. Despite the reduced yield of groundnut from the gicci system I do not believe it realistic to expect or even to try to persuade, farmers to grow sole crop groundnuts, certainly not whilst his production efforts are geared to a subsistence risk strategy.

(ii) Cereals intercropping with all mixtures of 3 varieties of maize, 2 varieties of millet and one of sorghum have been completed at IAR. Results indicated gain from mixing associated with differences in times to maturity. A series of large experiments were initiated at State locations in 1976, and continued in 1977. Each trial consisted of six main treatments as follows:

1. 6 maize varieties grown sole and mixed with (a) a standard millet and (b) a standard sorghum variety.
2. 6 millet varieties grown sole and mixed with (a) a standard maize and (b) a standard sorghum variety.
3. 6 varieties of sorghum mixed with (a) standard maize variety and (b) a standard millet variety.

Because of the complexity of these trials attempts were made to both sow and harvest them by IAR personnel. Despite feasible scheduling, factors such as ever-changing staff, fuel shortages, and mismanagement have meant that many trials were sown later. It is not intended to

continue this series because of these difficulties. The trials were sown at 16 locations which were:

Yelwa	Kachia
Bida	Sanaru
Isanlu	Bokkos
Omu-aran	Pankshin
Alapa	Kafinsoli
Yandev	Panda
Sabon Gida	Kano
Mokwa	Ladanawa

Results, from those logbooks available, are given in the following Tables:

Table H.I./12

Ear wt. maize varieties in kg. ha^{-1} grown sole

	Sanaru	Mokwa	Yandev	Alapa	Omu-aran	Panda	Mean
Borno Local	5545	4234	3332	3725	3305	3865	3968
S123	8030	4015	1723	5108	1311	5108	4216
U.V.E		3086	2212	1923	1967	4266	2691
NCB		4616	1434	2524	4097	2524	3039
O 96	7129	4561	1475	1382	4425	3365	3723
TZA 1	6774	7456	1472	1863	4561	3185	4219
TZA 2	5381						5381
TZA 3	4889						4889
							3769

Table H.I./13

Head wt. maize varieties in kg. ha^{-1} grown mixed with ex Borno millet

	Sanaru	Mokwa	Yandev	Alapa	Omu-aran	Panda	Mean
Borno local	5545	2786	3332	3727	3742	1562	3449
S 123	7538	4370	1218	2764	929	2884	3284
UVE		2242	2240	1743	2404	2464	2219
NCB		3906	1256	1082	5982	4326	3310
O 96	6746	3346	1666	733	5625	2404	3120
TZA 1	6966	7101	1366	961	3687	2343	3737
TZA 2	5927						5927
TZA 3	5463						5463
							3399

Mean ex Borno millet sole 2356 kg.
Mean ex Borno millet mixed 2353 kg.

Table H.I./4

Ear wt. maize varieties grown sole kg ha^{-1}

	Samaru	Mokwa	Yandev	Alapa	Omo-aran	Panda	Mean
Bono local	8276	2851	3305	4687	4916	3706	4637
S 123	8358	5681	1803	5708	628	3846	4337
UVE		1721	1038	2914	2322	3185	2242
NCB		3400	1475	2343	4971	2704	2979
O 96	8085	1562	1803	3245	5927	3485	4018
TZA 1	7566	5230	2513	1562	4998	4867	4456
TZA 2	6992						6992
TZA 3	6091						6091
							3997

Table H.I./15

Head wt. maize varieties grown mixed with SK 5912 sorghum except at Panda where RZ 1 was used, in kg ha^{-1}

	Samaru	Mokwa	Yandev	Alapa	Omu-aran	Panda	Mean
Bono local	7757	3187	2944	3665	4261	5168	4497
S 123	8904	5304	2103	2644	1338	3004	3883
UVE		1229	1857	2524	2731	1983	2065
NCB		3420	1748	1382	6063	4146	3352
O 96	7538	2696	1967	2704	3469	3125	3583
TZA 1	8522	4752	1639	721	4862	4326	4137
TZA 2	5681						5681
TZA 3	7456						7456
							3801

Mean SK 5912 sole 1885 kg.
Mean SK 5912 mixed 1988 kg.

Table H.I./16

Head wt. sorghum varieties sown sole in kg. ha^{-1}

	Mokwa	Yandev	Alapa	Omu-aran	Panda	Mean
C 74	3250	691	1502	1939		1346
Local	5244	1232	1322	1775		2393
FFBL	1065	1202	739	1502		1128
ML 4	2540	1472	1863	2130		2001
F.D. 1	5080	1652	2404	1666		2701
SK 5912	410	961	781	1174		832
YG					2764	
A 9025					2944	
500					2103	
Kano LA					4086	
Kano LB					2644	
RZ 1					4266	
						1969

Table H.I./17

Head wt. sorghum varieties sown mixed with 096 maize except Panda, where Bono local was used, in kg. ha^{-1}

	Mokwa	Yandev	Alapa	Omu-aran	Panda	Mean
C 74	4425	1304	1682	1775		2297
Local	6036	3185	1022	1475		2930
FFBL	1666	1270	901	1557		1349
ML 4	3633	1240	1622	1584		2020
FD 1	3933	1192	2824	1366		2329
SK 5912	328	847	1863	1229		1067
YG					2824	
A 9025					4507	
500					4507	
Kano LA					4326	
Kano LB					3425	
RZ 1					4326	
						2396

Mean maize sole 2338 kg.

Mean maize mixed 2674 kg.

Table H.I./18

Head wt. sorghum varieties grown sole in Kg ha^{-1}

	Mokwa	Yandev	Alapa	Omu-aran	Panda	Mean
C 74	4261	961	1682	2704		2387
Local	3906	1484	1202	2644		2309
FFBL	1065	1015	2584	1622		1572
ML4	2813	1124	1743	3485		2291
FD 1	4725	1304	1562	2464		2514
SK 5912	519	991	2043	3605		1790
YG					1863	
A 9025					2223	
500					2283	
Kano LA					2283	
Kano LB					1622	
RZ 1					1082	
						2094

Table H.I./19

Head wt. sorghum varieties sown mixed with ex Borno millet in kg ha^{-1}

	Mokwa	Yandev	Alapa	Omu-aran	Panda	Mean
C 74	4698	709	2404	2343		2539
Local	4752	691	3004	2464		2728
FFBL	3845	1106	1803	1352		2027
ML 4	4261	823	2043	1508		2159
FD 1	5244	1082	2464	2085		2719
SK 5912	1123	877	2163	4867		2258
YG					1923	
A 9025					3906	
500					1622	
Kano LA					2223	
Kano LB					2103	
RZ 1					1502	
						2367

Mean ex Borno sole 2614 kg

Mean ex Borno mixed 2291 kg.

Data for millet has not yet been extracted. Results have not been analysed and it is premature to draw conclusions. However, maize appears to show a consistent reduction in yield when grown mixed, particularly so if grown with millet. Two varieties, NCB and TZA 3, showed gain sown with both millet and sorghum.

Sorghum varieties, overall, showed a consistent trend to yield more mixed than when sown sole.

(iii) Cereals and Cowpea (L. Okiror; E. F. I. Baker)

Four experiments were done under this head.

(a) One was designed to observe growth and yield of an erect (RVU 4551) and a prostrate (1696) cowpea as plant density changed both sown sole and under maize varieties of different durations. Data has not been extracted but the general effect of increasing plant population was to reduce the number of secondary and tertiary branches. This reduction was accentuated by the presence of cereals.

(b) The second experiment, designed to investigate yield response of eight cowpea varieties sown sole and under five different cereals, failed. Neither mixed nor sole cowpea were sprayed against insect pests, and neither yielded grain.

The two remaining experiments were designed to investigate the cowpea plant type best suited to mixing with cereals, and to observe the physiological response by cowpea. to shade imposed by a canopy of sorghum.

(c) Two varieties of sorghum, SK5912, lax leaves at 60° angle to the stem, and 1389, erect leaves at 45° angle to the stem were sown at 30 May 1977. Two varieties of cowpea, Ife Brown, erect, and 2479 prostrate and spreading, were sown sole and with the sorghum on 19 July 1977. All were sprayed against insect pests with DDT/BHC at weekly intervals from flowering.

Results are given below.

Table H.I./20

Yield and Yield Components of Ife Brown and 2479 Cowpeas sole and mixed with sorghum varieties SK 5912 and 1389; and grain yield of sorghum.

	SEED SIZE ($g.1000\ seeds^{-1}$)	SEED POD^{-1}	PODS PLANT	SEED YIELD ($kg.ha^{-1}$)	SORGHUM YIELD
Ife Brown with	116.5	8.0	6.5	723.0	
with SK 5912	121.2	6.3	4.4	147.2	2715
with 1389	127.5	7.6	6.7	371.7	1665
Mean Mixed Ife Brown	124.4	7.0	5.6	259.5	
2479 Sole	179.1	5.4	5.3	349.2	
with SK 5912	158.8	7.8	3.6	233.6	2096
with 1389	179.3	7.9	2.4	196.7	1786
Mean Mixed 2479	169.1	7.9	3.0	215.2	
Se +	24.2	.9	1.3	122.5	
Mean mixed with SK5912	140.2	7.1	4.0	190.4	2406
Mean mixed with 1389	153.3	7.8	4.6	284.2	1726

Ife Brown cowpea. appeared to be sensitive to light intensity in that yield and all yield components were improved by sowing under sorghum 1389, which allowed 18% more light to reach the cowpea because of the erect

leaves, compared with sowing under SK 5912. This response was not obtained by cowpea 2479, except for seed size.

Despite the reduced yields of cowpea due to mixing with sorghum, the total return from mixing is greater than that from sole crop cowpea.

AM 233(77)

In the second experiment Ife Brown and 2479 cowpeas were sown on 19 July under an established crop of SK 5912 sorghum sown 31 May or where no sorghum was planted, sown solo. Sorghum was removed leaving the cowpeas as a sole crop depending on the growth stage of the cowpeas or not removed in the case of the control plots. A split-plot design with four replications was used with cowpea varieties as whole plots and treatments as sub-plots. Cowpeas were sprayed with DDT/BHC at weekly intervals beginning at first flowering.

Cowpea growth stage at sorghum removal:

First flowering (FF)

50% Flowering (50%) - 50% of the plants in each plot with flowers.

100% Flowering (100%) - 100% of the plants in each plot with flowers.

Table H.I./21.

Yield and Yield Components of Ife Brown and 2479
Cowpeas sole and mixed with short Kaura 5912 sorghum

	SEED SIZE ($g.1000\ seeds^{-1}$)	SEEDS POD^{-1}	PODS $PLANTS^{-1}$	SEED YIELD $kg.ha^{-1}$
Ife Brown Sole	13[illegible].4	6.3	6.0	1441.1
Sorghum removed FF	141.9	9.8	4.4	359.6
50%	142.3	8.1	4.3	218.6
100%	126.0	7.3	2.3	66.3
Sorghum not removed	125.8	7.5	4.8	217.3
2479 Sole	170.2	6.5	5.5	717.9
Sorghum removed FF	184.3	5.8	4.9	205.3
50%	200.3	5.0	3.3	28[illegible].8
100%	147.1	6.4	2.9	203.2
Sorghum not removed	161.4	7.7	2.0	92.5

(SK 5912 yielded 3453 kg with Ife Brown and 3067 with 2479).

Table H.I./22.

Nodes per stem of Ife Brown and 2479

	Number Nodes per Stem	
	Ife Brown	2479
Sole Cowpeas	16.2	21.2
S Sorghum removed FF	8.2	11.3
50%	8.3	12.6
100%	7.0	-
Sorghum not removed	9.0	9.4
Mean of cowpeas grown with sorghum	8.1	11.1
% of Sole	50	48

Removing the sorghum crop before 100% flowering of the cowpea increased seed size in both varieties, seeds per pod in Ife Brown and seed yield in 2479 (Table H.I./20). Fewer pods per plant for the mix-cropped cowpeas may have resulted from fewer nodes per stem (Table H.I./22) in these two varieties. Shade caused a 50% reduction in the number of nodes per stem thus fewer sites available for peduncle and pod formation and fewer pods per plant.

Although a slight yield gain was realized from the early removal of sorghum and leaving the cowpea to grow as a sole crop during reproductive growth stages, yield was not up to that of the sole crop. Number of nodes per stem were set during vegetative growth stages so peduncle formation was limited to those nodes. Perhaps earlier removal of sorghum may be more beneficial to cowpea yield.

Cowpea yields were very much reduced by the shade imposed by a sorghum crop. Possible compensatory mechanisms of the two cowpea varieties tested are seed size and seeds per pod.

IV. Sorghum-Cowpea Intercropping (B. Kaig

This experiment started last growing season aimed at comparing the performance of a cereal-cowpea mixture against sole crop cereal and sole crop cowpea. Two sorghum varieties, HP 3 (short and early maturing) and YG 5760 (tall and late maturing) were grown sole and intercropped with two cowpea plant types, '2479' (spreading) and '341' and '29' (both semi-erected). All plots were four ridges wide and six metres long. In the intercropped plots sorghum was planted on the two inner ridges and cowpea on the outer ridges. Treatments were arranged in randomized complete blocks replicated six times. Half of the field was sprayed while the other half half was unsprayed. Vetox 20 was applied at 1.25 gallons in 50 gallons of water/ha/application, with six consecutive applications at weekly intervals, starting ten weeks after planting. Yields results are given in the table below.

Table H.I./23.

Sorghum grain yield when grown sole and intercropped with cowpea varieties (kg/ha).

Cropping System	Sorghum YG 5760	Variety HP 3	MEAN
Sole	2336	1238	1787
Intercropped:			
with '2479'	3180	1626	2403
" '341'	2581	1545	2063
" '29'	3350	1965	2658
MEAN	2862	1594	2228

YG-5760 significantly out-yielded HP-3 when grown sole or intercropped with cowpea. Both varieties yielded more when intercropped with cowpea than when grown sole. On the average, YG-5760 gave 701 kg/ha (30%) and HP-3 gave 474 kg/ha (38%) more grain yield when intercropped than when grown as a sole crop. However, these differences though seemingly large, were not significant.

Table H.I./24:

Seed yield of sprayed and unsprayed cowpea when grown sole and intercropped with sorghum (kg/ha)

Treatment	Cowpea '2479'	'341'	Variety	'29'	MEAN
SPRAYED:					
Sole	1014	1590		978	1194
with HP-3	1499	1827		1169	1498
with YG-5760	1827	1115		1173	1377
Mean	1447	1511		1173	1377
UNSPRAYED:					
Sole	539	676		649	621
with HP-3	1115	548		658	774
with YG-5760	914	566		420	633
Mean	856	597		576	676
MEAN	1151	1054		874	1026

'2479' gave about 72% (560 kg) more yield when intercropped with either HP 3 or YG 5760 than when grown as a sole crop. Intercropping '341' with HP 3 did not affect seed yield but yield was depressed by about 26% (292 kg) when it was intercropped with the taller YG 5760. '29' gave only very slight increase in yield (about 10%) when intercropped with either HP 3 or YG 5760. There were highly significant differences in yield between sprayed and unsprayed plots for all three varieties when grown sole or intercropped (see above table)

V. Sorghum-Millet Intercropping (B. Kaigama)

This experiment started in 1975 was designed to determine the optimum spacing for the intermediate season sorghum variety RZ 1, when planted sole and when intercropped with millet at Kano. The spacing tested were 20, 30 and 40cm between stands on ridges 75cm apart. Plots were four ridges, six metres long. In the intercropped plots sorghum was planted on the two inner ridges at one of the three spacings and the two outer rows were planted with Ex-Borno millet at 30cm spacing. Treatments were replicated six times and arranged in a latin square.

Grain yield from the 1977 crop was very low. This was due to poor germination caused by an extended period of drought after sowing. Though the gaps were filled, most of the late sown plants did not produce heads by the end of the rains.

Grain yield for the three years is given in the table below. Grain yield of sorghum (kg/ha) sown at various spacing as a sole crop and when intercropped with millet (Table H.I./25).

Year	Cropping System	Spacing(cm) 20	30	40	Mean
1975	SOLE	2091	2112	1835	2013
	INTERCROPPED	2240	2283	2005	2176
1976	SOLE	602	676	903	727
	INTERCROPPED	861	834	667	787
1977	SOLE	407	429	603	480
	INTERCROPPED	503	695	208	469

No significant differences in grain yield between the various spacings or between sole and intercropped sorghum was observed in any of the years. However, intercropped sorghum almost always yielded slightly higher than the sole crop sorghum.

VI Maize/Cowpea Intercrop (P.N. Egharevba)

Maize as is grown now is one plant per stand at close spacing at different row spacing. With more emphasis being placed on mixed cropping because of its advantages there is need to study the existing pattern of planting with a view to modifying it to make room for the accompanying mixed crop.

The objective of this trial was to determine the performance of mixed maize and cowpea at different number of plants per stand.

The following spacing were used;

One plant per stand 28 x 75cm
Two plants per stand 56 x 75cm
Three plants per stand 84 x 75cm.

One stand of maize in each case was alternated by a stand of cowpea giving a stand population of 46,500 plants per hectare for each crop. Control plots of sole maize and cowpea were also grown.

Data collected are not fully analysed but preliminary yield data are shown in Table H.I./26. The combined yield of alternating 2 plants per stand of maize with 2 cowpeas plants per stand is substantially higher than alternating 1 or 3 plants per stand respectively. This is an indication that it may be profitable to increase the number of plants per stand while at the same time increasing the distance between plants along the row.

Table H.I./26:

The influence of spatial arrangement on Grain Yield of mixed maize and cowpea

Crop Mixture	Pls	Grain Yield (kg/ha)			100 G.wt. gm.	
		Maize	Cowpea	Total	Maize	Cowpea
Maize/cowpea	I	2659	1834	4493	289	146
	II	2543	2085	4628	281	144
	III	2180	1723	3903	276	140
	Mean	2461	1881	4341	282	143
	S.E.	281	215	497	32	16
Solo Maize	I	2718	-	2718	274	-
	II	2468	-	2468	286	-
	III	2023	-	2023	261	-
	Mean	2403	-	2403	274	-
	S.E. ±	275	-	275	31	-
Solo Cowpea	I	-	2437	2437	-	153
	II	-	2511	2511	-	156
	III	-	1908	1908	-	148
	Mean	-	2285	2285	-	152
	S.E. +	-	261	261	-	17

H.I./2/5

Mixtures investigating plant competition and population (E.F.I. Baker)

Earlier experiments investigating mixtures of cereals have established that successful mixtures depend upon the component crops being complementary to one another. Results have demonstrated that mixing a tall, fast growing cereal (e.g. millet) with a shorter slow growing cereal (e.g. sorghum) will give more yield from a unit of land than had the component crops been grown sole. This gain may be partly attributed to the fact that the reproductive phases of the components do not overlap, either in space or time, and thus do not compete with one another for the environment. Whether the competition is mainly for light or nutrients or water is not yet established, but there is considerable evidence that gain from mixing is associated with difference in height of the component canopies. Since these experiments were conducted at a population normal for sole crops, and since yield comparisons between mixed and sole crops were made at the same plant population then gain from mixing was because individual plants yielded more.

Yield per unit area is a function of yield per plant and number of plants. Simply Y = YP, when Y = yield/unit area, Y = yield/plant and P = number of plants. An optimum plant population is one that maximums Y, and, where cereals are concerned, this optimum falls on a second degree curve. Thus, if Y decreases whilst Y increases then P is sub-optimum; if Y decreases whilst Y also decreases, then P is above optimum. In the mixtures decribed above Y increased and Y also increased. It is argued, therefore, that although the plant population used was that considered optimum, because of decreased inter plant competition resultant from complementary plant habit, that one or both of the components was at sub-optimum population and that yield per unit area from a mixture may be increased further by raising plant population. To test this hypothesis two series of experiments have been done. The first considers mixture of a range of population of both 096 maize and short kaura sorghum, the other selected plant population but a range of maize varieties of differing height mixed with short kaura sorghum.

There were four experiments in the first series, from 1975-77, one at Mokwa (1975) and three at Samaru. Yield results are given in Table H.I./27.

Table H.I./27:

Yield as kg grain ha^{-1} at 14% m.c. for 096 maize
Sole crop yield as kg grain $\frac{1}{2}$ ha^{-1}

Proportion of Sorghum sole crop population		Proportion of maize sole crop population .53	.85	1.06	1.33	1.60
	1975(M)	1291	1810	2240	1557	2025
	1975	1417	1835	2677	1785	2240
.65	1976	1853	2244	2499	2391	3026
	1977	1835	1707	2161	1608	2575
	Mean	1599	1899	2394	1835	2466
	1975(M)	1145	1734	2054	2417	1595
	1975	1873	2139	2101	2582	1936
.85	1976	1751	2068	2074	2108	2686
	1977	1697	1746	2309	2082	1875
	Mean	1617	1922	2134	2297	2023
	1975(M)	1266	1873	2291	1709	1898
	1975	2253	2189	2417	1639	1886
1.05	1976	1502	2448	2295	2595	1785
	1977	1559	1697	2171	2023	1697
	Mean	1645	2052	2293	1991	1817
	1975(M)	1278	1683	1417	1594	2076
	1975	1367	2038	2126	2620	2113
1.25	1976	1428	1921	2533	2193	1949
	1977	1707	2023	1638	2210	1588
	Mean	1445	1916	1929	2154	1932
	1975(M)	1418	1342	1759	1493	1949
	1975	1797	2297	1886	2050	1974
1.45	1976	1190	1343	1343	1598	2301
	1977	1776	1648	2052	2171	2151
	Mean	1545	1718	1760	1828	2094
	1975(M)	1601	1778	1734	1132	1582
	1975	1753	2493	2639	2310	2171
Sole Crop	1976	1598	2020	2063	1887	1981
	1977	2092	2102	2487	2269	2398
	Mean	1761	2098	2231	1900	2033

There are many ways of interpreting table H.I./27 but from the point of view, of this report the simplest is to compare mean population response for the sole-crop and for mixed maize.

Mean yield were:

% Sole crop optimum	Sole maize	Mixed maize
.53	1785	1613
.85	2155	1913
1.06	2244	2142
1.33	2022	2083
1.60	2054	2070

For sole maize $Y = 900.3 + 2285.4\,x - 1009.0\,x^2$; $R^2 = .7090$

and maximum yield was at $x = 1.13$

For mix maize $Y = 575.4 + 2463.6\,x - 973.6\,x^2$; R^2 .8786

and maximum yield was at $x = 1.26$

x = proportion of sole crop "optimum" population.

Yields for sorghum are not yet analysed, but for maize (a) the mixture yielded best when plant population was raised to 1.26 "optimum" and (b) mixed maize did not outyield sole maize.

Residual Effects of Sole and Intercropped Legumes (E. Asenine)

In 1976 soybean and cowpea were either planted sole or intercropped with maize (096). In the intercropped treatments, each of the legumes constituted ½ of the plant population. In 1977, maize was subsequently grown to determine the residual effects of the treatments (sole and intercropped).

The mean grain yield of maize as influenced by previous (1976) sole cropping and intercropping of maize with soybean or cowpea at Samaru in 1977 is summarised below:-

Previous Treatment	Mean Grain Yield (kg/ha)
Sole Soybean without nitrogen	4365
Soybean + Maize without nitrogen	2550
Soybean + Maize with nitrogen	2555
Sole cowpea without nitrogen	4069
Cowpea + Maize without nitrogen	2362
Cowpea + Maize with nitrogen	2231
Sole Maize without nitrogen	2108
Sole Maize with nitrogen	2308
S.E. ±	208

* N was applied at 70 kg/ha N.

The results showed that the maize which was subsequently grown in the sole-cropped soybean or cowpea plots gave significantly higher yields over the maize in the intercropped legume plots.

The yields from previous intercropped legume plots were not significantly different from one another or from previous solecropped maize plots.

The results also indicated that little of any residual benefits would be derived from soybean/maize or cowpea/maize intercropped where the legume constitutes ½ or less of the total plant population.

Sub-programme: H.III/3 Weed Control and Tillage.

Introduction

A major change in the terms of reference of the weed science programme was approved by the Professional and Academic Board in June 1977. The objective of general weed control recommendations is defined as:- "To reduce or eliminate competition from weeds for at least seven weeks after sowing the crop, in the cheapest and most effective way in all farming systems, without reducing yields and with the main intention to reduce or eliminate drudgery".

Profitability

Profitability calculations, in these reports are based on the following notional prices observed by the Agric Economic section during 1977.

Commodity	Price/kg
Seed cotton	32k
Groundnut	40k
Millet	20.75k
Maize	29.27k
Sorghum	20.08k
Cowpeas	34.23k
Wheat	29.29k
Rice	59.45k
Manhours	36k
Single superphosphate	N1.50/50kg
Calcium ammonium nitrate	N2.00/50kg
Compound fertiliser	N2.00/50kg
Tractor hours	N1.50/hour

Exact herbicide costs are used where a Nigerian price has been established, otherwise an average figure of N10.00 per kg ai/ha is used for herbicides still under patent or N5.00 for older materials which are now 'off-patent'.

Presentation of results

In the following reports, the significance of the difference of a treatment mean from an appropriate no-herbicide check is often expressed by placing the exact 'P' value in brackets adjacent to the mean.

Weed control technology

Two experimental research tools were developed in the Weed Science Section in 1977. The 'Shrouded ground metered' Ground Metered Shrouded disc (GMSD) very low volume herbicide applicator was developed for very accurate controlled droplet application (CDA) in small plots. It was used in the 1977 experiments in the hoe farming and animal power systems. This machine is being developed for hoe farmer use by the Agricultural Engineering Section.

A straddle row toolbar fitted with proprietary rolling cultivators units was designed by Mr J.E.L. Boyd of ITDG and further developed by section staff. It was designed primarily for experimental incorporation of herbicides in small plots. The results of animal power experiments with this unit are now applicable to full sized tractor operations. In spite of its high unit cost this machine appears to have potential as an animal power toolbar and it is now in pilot scale production in Zaria.

Partially mechanised weed control

During 1977, a new programme of experiments to produce herbicide recommendations for crop productions schemes was started at States Experimental Sites. The results of these experiments have not yet been fully summarised but will be circulated to States as soon as possible.

The general conduct of these trials by States staff leaves much to be desired.

The production of firm recommendations for particular zones will be delayed as a result.

Sub-project H.III/3/i Herbicide use techniques in hoe farming systems: Researcher J. Ogbarn.

Three techniques of herbicide application were compared factorially on old vs split ridges in millet-sorghum (see Sub-project H.III/3/ii) and sole crop cotton (see Sub-project C.I/3/3.i). Table H.III/3/1 shows the profits associated with each treatment combination averaged over both crops.

Table H.III/3/1

The profitability/ha of formulations and modes of herbicide application in the hoe farming system

Herbicide formulations	Herbicide applied to Old ridge	Herbicide applied to Split ridge	Formulation means
Herbiliser	₦149.30	₦55.81	₦102.56
Herbirock	₦129.02	₦77.13	₦103.08
C D A	₦185.29	₦81.78	₦133.54
Mode means	₦154.54	₦71.57	₦113.06

In general it can be seen that CDA application with the ground-metered shrouded disc prototype was more profitable than herbiliser or herbirock broadcast by hand. This was inspite of crop damage in millet-sorghum caused by incorrect operation of the sprayer.

In 1977, application to old ridges was twice as profitable as application to split ridges. This result might be reversed in seasons with heavy rain in June and July.

Project H.III/3/1

Sub-project H.III/3/1/11 Weed control in millet, sorghum mixtures

Experiment AP 268(77) Crop establishment techniques in the millet sorghum mixture at Samaru.

This experiment continued the studies to develop an agronomic package recommendation for herbicide use in hoe farmers millet-sorghum mixture on the basement complex soils at Samaru.

The crops were sown into the ridges and furrows remaining after the 1976 season. Mainplot treatments contrasted 'sown in the furrow, followed by ridge splitting' with 'sown on the ridge on old ridges'. The sub-plot treatments contrasted three methods of linuron herbicide application with a no-herbicide check treatment.

Treatments

Main-plot Sown on old ridge after pre-plant herbicide application

vs

Sown in furrow followed by ridge splitting and herbicide application

Sub-plot 0.8 kg ai/ha linuron herbiliser

vs

" " " herbirock

vs

0.4 " " " CDA pre-plant or post splitting

f.b. 0.4 " " " CDA post establishment.

no-herbicide check

Basal crop agronomy:- According to recommended practises

Field Operations

24/5/77	Millet planted
27/5/77	'Sown on ridge' herbicides applied
2/6/77	Sorghum planted
13/6/77	Millet thinned and spot weeded
23/6/77	Sorghum thinned
11/7/77	Ridges split in the 'sown in furrow' treatment
14/7/77	Post-splitting herbicides applied

19/7/77 2nd application of CDA linuron to 'sown on ridge' treatment.
21/7/77 1st application of CDA linuron to 'sown in furrow' treatment.
28/9/77 Millet harvested
14/10/77 2nd application of CDA linuron to 'sown in furrow' treatment.
19/12/77 Sorghum harvested.

Results

Weed control in 1977 season was complicated by the unprecedented low rainfall in July. Herbicides performed inefficiently on a drying soil profile and ridge splitting was laborious and slow. The cereals sown in the furrow were overgrown by weeds and had to be spot-weeded several times before they were big enough for the ridges to be split. The ridges were then too dry for easy splitting. Hoe farmers in the surrounding area experienced exactly the same problems and in some cases did not split their ridges until early August. Millet yields were seriously reduced by insect damage. Millet yields were further reduced in the CDA treatments when the July applications were accidentally made with a reversed disc (Spraying upwards at crops rather than downwards at weeds).

The data in tables H.III is therefore not typical of the Northern Guinea climate. On crops sown in the furrow the herbicide did not reduce weeding hours or increase grain yields. In crops sown on the ridge, herbiliser and herbirock reduced hoeing hours considerably without seriously reducing yields. Even the CDA treatment on the ridge was more 'profitable' then the no-herbicide check in spite of spectacular damage caused by the incorrect application.

Table H.III Millet-sorghum grain yields (kg/ha) and weed control inputs (man hours/ha) at Samaru, 1977.

Treatment	Linuron dosage kg ai/ha	Grain yields millet	Grain yields sorghum	Hoe labour 1st seven weeks	Hoe labour Maturation
Sown in furrow followed by ridge splitting					
Herbiliser post-splitting	1.6	91(.562)	799(.254)	1239	506
Herbirock post-splitting	1.6	70(.605)	696(.074)	1267	546
CDA post-splitting + lay bye	0.8+0.8	68(.702)	353(.000)	1224	638
No herbicide	-	64	971	1296	580
Sown on old ridge					
Herbiliser pre-plant	1.6	222(.920)	809(.317)	487	403
Herbirock pre-plant	1.6	173(.277)	892(.641)	560	288
CDA pre-plant + post-emergent	0.8 + 0.8	58(.006)	553.4(.000)	440	200
No herbicide		226	906	872	612

It should be noted however that if a farmer accounted for his own labour at the opportunity cost observed by the Socio-Economics Department in 1977, all treatments would have made an absolute net loss from the cost of weed control alone!

Table H.III 3 Millet-sorghum costs and profits/ha at Samaru, 1977

Treatment	Crop value	Weed control costs	Profit from herbicide	Net profit.
Sown in furrow				
Heribiliser	₦178.73	₦644.20	₦ 2.10	-465.47
Herbirock	₦153.65	₦668.68	-₦47.46	-515.03
CDA	₦84.64	₦686.32	-₦134.11	-601.68
No herbicide	₦207.79	₦675.36	-.	-467.57
Sown on old ridge				
Herbiliser	₦207.11	₦336.40	₦166.72	-₦129.29
Herbirock	₦213.87	₦321.28	₦188.60	-₦107.41
CDA	₦122.73	₦268.00	₦150.74	-₦145.27
No herbicide	₦238.23	₦534.24	-	-₦296.01

Much of the cost of weed control in the furrow was due to the very high cost of splitting the dry ridges in July, this required 980 man hours /ha instead of the 350 normally required to split moist ridges. Even if allowance is made for this however, the break-even yield with this mode of crop establishment would still have been 2076 kg of grain/ha for the most cost effective mode of herbicide application (herbiliser). The lowest break-even yield for crops sown on old ridges would have been 1335 kg/ha. (CDA)

There is only limited scope for reducing hoe labour hours because the hoe farmer characteristically does one combined weeding and thinning operation which absorbs about 200 hr/ha even on a completely clean ridge. If he also splits the ridges under ideal conditions the irreducible weed control cost will be ₦198, equivalent to a break-even yield of 986 kg/ha.

At present relative price it is desirable to eliminate hoeing completely, this is technically possible only with the use of a metered and shrouded CDA applicator using contact herbicides on the unprepared seedbeds used by hoe farmers.

Current recommendation:- None

Proposed recommendation:- 1.6 kg ai/ha of linuron is tolerated by both millet and sorghum in sole crop at Samaru, but there is clearly much to be done before an appropriate agronomic package can be recommended.

Project H.III/3/2 Weed control with the animal power system.

Sub-project H.III/3/2 vi Weed control in the millet-sorghum mixture.

Researcher J.E.A. Ogborn

Experiment AM 301(77) Crop establishment techniques on basement complex soils.

Timely establishment of cereals on the basement complex soils is not usually done by animal power farmers. Both millet and sorghum need to be sown early in the rains before the old ridges are wet enough to be split with a ridger plough. The few animal power farmers near Samaru either use 'hand-hoe' techniques or wait until the ridges are wet enough to split easily. They therefore lose either the benefit of using work bulls or the increased yield from early sowing. This may be the main reason why animal power farming has not been widely adopted on the heavy soils of the northern guinea zone.

Two techniques which had potential for early crop establishment without ridge splitting were therefore compared in 1977 at Samaru for their weed control characteristics in an 'alternate row' millet sorghum mixture. Linuron at 0.8 kg ai/ha was applied factorially with a ground matered shrouded disc VLV sprayer.

Furrow drilling

Crop establishment was performed by furrow drilling with a hand metered sowing tube fixed behind a ridger plough running in an old furrow. 0.4 units of linuron were then applied pre-emergent.

When the crop had grown sufficiently, the old ridges were split back onto the crop. A further 0.4 units of linuron was then applied onto the new ridge. Subsequent weed control was maintained by hand hoeing and remoulding.

Straddle drilling.

The prototype Boyd rotary cultivator fitted with an improvised cross-bar and sowing tube was used to drill into the crown of the old ridge. Herbicide was applied pre-emergent with the same VLV sprayer. Subsequent weed control was intended to be entirely by straddle row cultivation without hand hoeing. Equipment with a high enough clearance to do this was not available when needed and a considerable amount of hoe weeding had to be done instead.

Experimental operations.

1/6/77	Millet and sorghum sown by both techniques.
3/6/77	Linuron applied to the straddle treatments pre-em.
	Linuron ½ rate applied to the furrow treatment pre-em.
20-22/6/77	Crop thinned by hand.
30/6/77	Hoe weeding started in the 'Straddle only' treatment.
7-8/7/77	Fertiliser side banded on straddle treatments.
	Fertiliser broadcast on the furrow treatment.
19/7/77	Ridges split on both furrow treatments
20/7/77	'Furrow only' plots and both straddle treatments weeded.
29/7/77	Linuron ½ rate re-applied to the 'furrow + linuron' treatment post-em.
15/8/77	Remoulding of straddle treatment done
28/9/77	Straddle cultivation with new high clearance toolbar started.
5/10/77	Millet harvest.
13/12/77	Sorghum harvested.

Results.

The recommended crop population for 76 cm ridges is 21.5 thousand stands per ha. Both establishement techniques produced higher population of single stands but straddle planting increased establishment very significantly from 25 to 31 thousand per hectare in the millet crop.

In tables 4 and 6 the exact 1 tailed significance of each linuron effect as shown in brackets against the linuron mean. In table 5 the exact 2 tailed significantly of each response is shown similarly.

Table H.III 4 Weed control inputs (as manhours/ha) and costs.

	Establishment (1st 49 days)			Maturation period		
	dosing	cultivation	Cost	Hoeing	Cultivation	Cost
Furrow only	46	13	₦21.23	71	11	₦29.58
Furrow + linuron	0(.261)	15(.337)	₦13.38	77(.445)	9(.013)	₦31.[illegible]
Straddle only	229	13	₦87.10	23	9	₦11.[illegible]
Straddle + linuron	92(.052)	6(.051)	₦43.22	133(.017)	10(.29)	₦51.62

Note 1. Includes manhours used in sowing the crop

Table 4 shows that furrow drilling with linuron eliminated hoe weeding during the first seven weeks.

Table 5 reveals that the overall effect of linuron herbicide was to reduce total weeding effort, straddle establishment and cultivation required more manhours for weed control but was more profitable because of a larger overall yield increase. The interaction between straddle cultivation and linuron on weed control was small but the overall yield and monetary responses were positive.

Table H.III 5 Responses to cultivation and linuron herbicide as man-hours and yield.

	Establishment period		Maturation period		Total responses	Millet grain	Sorghum grain	Monetary values
	Hoeing	cultivation	Hoeing	cultivation				
uron	-91.5(.114)	-2.50(.358)	58(.097)	-.5(.323)	-36.5	81(.482)	155(.036)	₦60.53
addle	137.5(.052)	-4.50(.117)	4(.897)	-.5(.615)	436.5	571(.000)	139(.055)	₦93.43
eraction	-45.5(.450)	-4.50(.117)	52(.025)	1.5(.025)	3.5	-65(.572)	163(.028)	₦13.42

The abnormally low July rainfall in 1977 caused ridge splitting to be delayed on the 'furrow only' treatment. This would normally have been done about two weeks earlier and made it necessary to 'spot weed' round some of the crop before splitting the ridges.

The late delivery of the new straddle equipment prevented more than one post-emergent cultivation during the first seven weeks in the 'straddle only' treatment. None were required in the 'straddle + linuron treatment until it was too late to do it with the equipment then available. This made it necessary to do more hoe weeding during the maturation period. A major effect of the linuron being to delay weed growth as well as reducing it.

Table H.III 6 Crop yields as kg grain/total ha

	Millet	Sorghum	Gross value	Net profit
Furrow only	261	750	₦203.04	₦163.62
Furrow + linuron	407(.108)	742(.931)	₦230.98	₦196.04
Straddle only	897	726	₦325.05	₦310.26
Straddle + linuron	913(.443)	1044(.003)	₦392.98	₦337.52

Note 2. Less cost of seed and depreciation

Table 6 confirms that linuron did not reduce yields in either system and as it definitely did reduce weeding effort during the first seven weeks it is formally recommendable. Linuron increased millet yields (non-significantly) with furrow drilling whereas sorghum was little affected. In contrast there was a highly significant increase of sorghum yield from linuron in the straddle system.

The straddle system gave higher overall yields and better profit in spite of the need to do more hoe weeding as a result of the late delivery of modified toolbars.

This experiment needs to be repeated in a more typical season but the current results have shown that the ridger plough can be adopted for early cereal crop establishment in basement complex soils.

The true profitability of the straddle system was probably understated in this experiment. It is expected that hand hoeing will be reduced to one spot weeding combined with thinning when the improved straddle toolbar is available throughout the season.

Project H.III 3/4.1 - Control of parasitic weeds
Researcher: J. Ogborn and R. Mansfield

This project includes the following aspects, (i) foliar herbicide application IIDFOLA), (vii) studies of the variability of striga attack on different crop species in different ecological zones (viii) soil applications of germinators and/or herbicides to control striga.

Sub-project H.III 3/4.1 vii - Ecological studies

The object of this project is to find regional differences in striga attack on millet and upland rice.

Tours were made of the Sudan and Guinea zones from August to December 1977. Extent of attack, crop damage, host preference, stage of striga development and striga mortality were observed at sites approximately 20 km apart on a North-South traverse through the Sudan and Guinea ecological zones. Places visited are recorded in Figures 1 and 2, which also present results.

The following conclusions were made:

1. Severity of striga attack on millet (gero and maiwa) varied with rainfall. In those areas with light rains during millet's period of striga susceptibility. i.e. The Sudan Zone and Southern Guinea Savannah, millet was attacked. This was because rainfall was also light or absent during millet harvest. Striga was therefore able to set and ripen seed. This process repeated annually for many seasons would cause the strains preferentially attacking millet to build up in the environment.

Conversely, in those areas such as the Northern Guinea Savannah where the soil is too wet after planting to allow striga to complete its life cycle and produce mature seed before harvest, such strains would diminish yearly, so that only the sorghum-attacking strains would survive and only the sorghum would be attacked in this environment.

In the Sudan zone the rains are usually short enough to ensure that the crop matures in dry weather so that striga can always germinate and mature on the drying cycle at the end of the rains even if it has not already done so in the rather dry soil conditions which normally prevail during the main period of crop growth.

The Southern Guinea Savannah by contrast experiences first a rainy period, at which time farmers plant, then a period of intermittent drying, then a period of heavier rains in late July/August when crops are maturing. The drying period allows striga to germinate and attach to millet. The Northern Guinea zone is uniformly wet during early crop life and prevents germination of any millet attacking strain which might exist. Sorghum is attacked in the Northern Guinea because even if the soil is too wet for

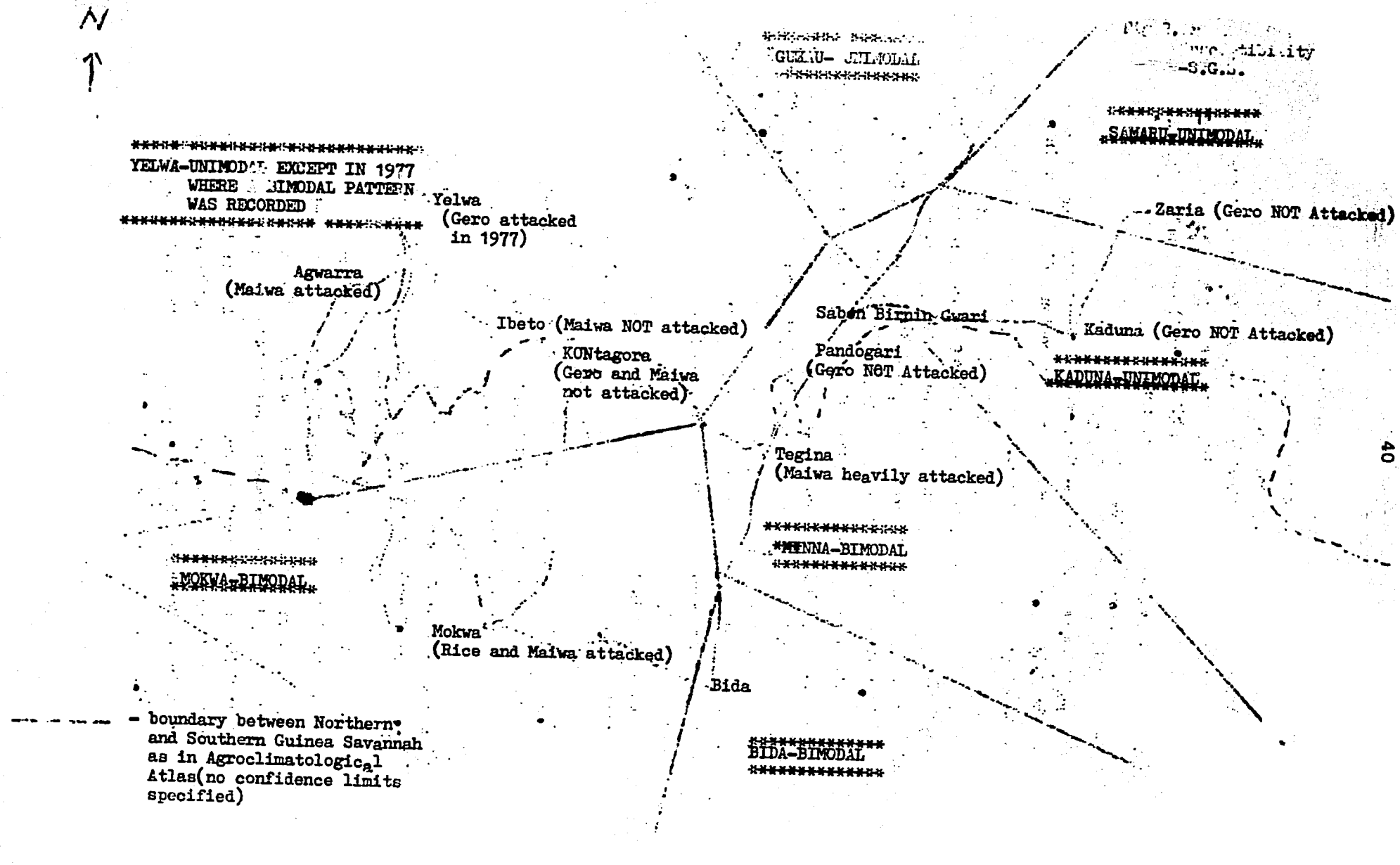
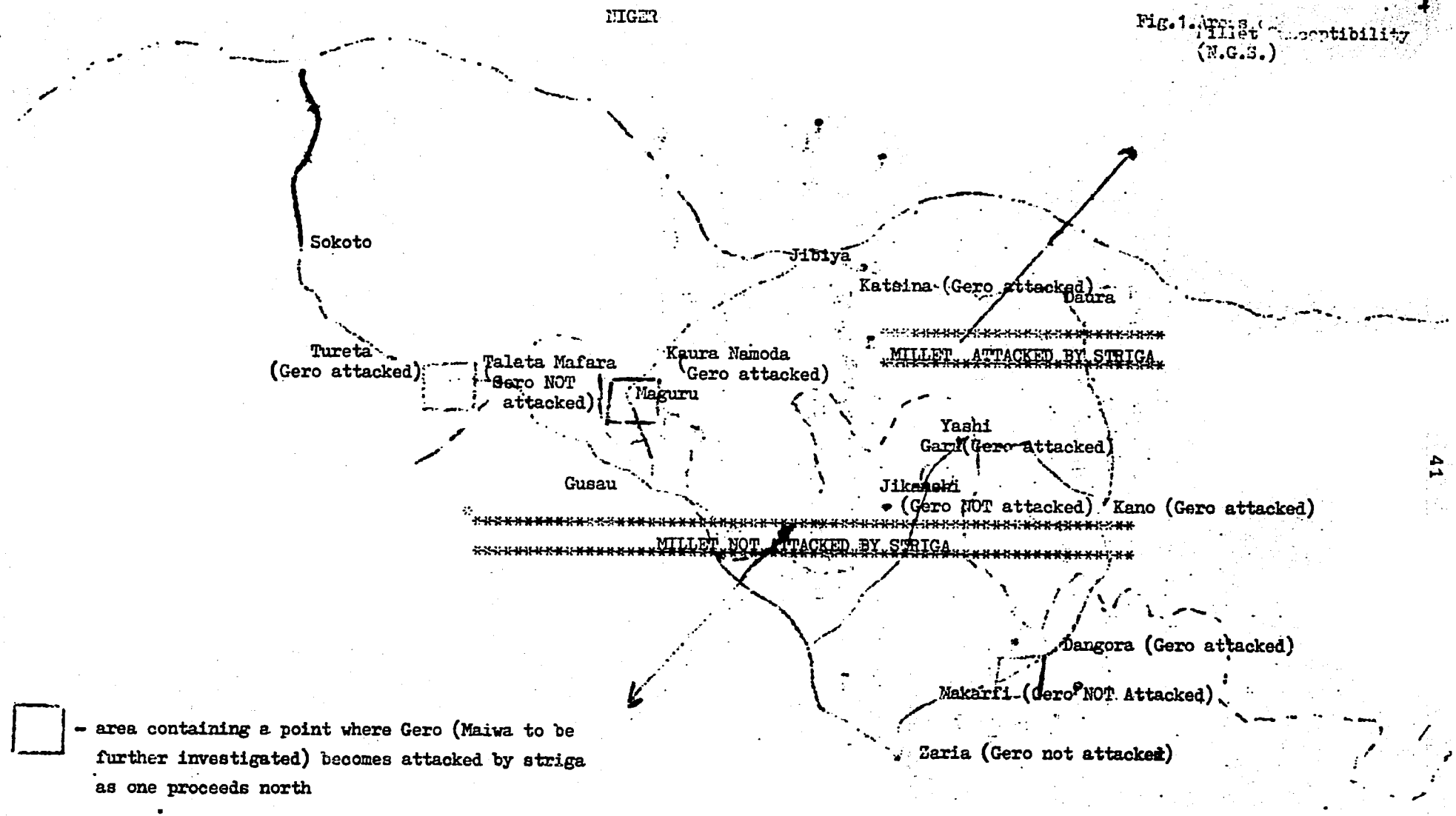

N
GUZAU- UNIMODAL
SAMARU-UNIMODAL
YELWA-UNIMODAL EXCEPT IN 1977
WHERE BIMODAL PATTERN
WAS RECORDED
Yelwa
(Gero attacked
in 1977)
Zaria (Gero NOT Attacked)
Agwarra
(Maiwa attacked)
Ibeto (Maiwa NOT attacked)
KONtagora
(Gero and Maiwa
not attacked)
Saban Birnin Gwari
Kaduna (Gero NOT Attacked)
Pandogari
(Gero NOT Attacked)
KADUNA-UNIMODAL
Tegina
(Maiwa heavily attacked)
MINNA-BIMODAL
MOKWA-BIMODAL
Mokwa
(Rice and Maiwa attacked)
Bida
BIDA-BIMODAL
- boundary between Northern
and Southern Guinea Savannah
as in Agroclimatological
Atlas(no confidence limits
specified)

Fig.1. Areas of Millet Susceptibility (N.G.S.)



- area containing a point where Gero (Maiwa to be further investigated) becomes attacked by striga as one proceeds north

——— boundary separating SUDAN zone from the NORTHERN GUINEA SAVANNAH zone.

germination during the rainy season, sorghum's long life cycle permits germination and striga seed production well into the drying cycle of September/October, long after the millet has been harvested. As a result, levels of the sorghum strain in the environment would be maintained.

2. This hypothesis can be applied to rice in the Southern Guinea zone as well: dry periods after planting allow germination to occur soon enough to allow striga to complete its life-cycle and to produce seed before harvest. Whereas any crop in the Northern Guinea zone with a life-cycle short enough to permit planting early in the rainy season and complete harvesting before the striga can produce mature seed, will eventually develop zonal immunity to striga. This explains the existence of biotypes of striga. Provenance studies have been started to confirm this.

Observation plots were started in June/July 1978 in order to confirm results presented in Figures 1 and 2 which show that the upper and lower boundaries of millet and rice immunity approximately follow the upper and lower boundaries of the Northern Guinea Savannah zone.

3. Marked seed mortality caused by insect predation was observed on almost all fields in the Sudan zone where striga infestation was severe and wide spread. Predation was rather evenly distributed throughout the field. The agent is not yet determined.

Sub-project H.III 3/4.1 viii - Striga control by soil application

1977 - 8 Season

The first year of testing pre-plant incorporated chemicals for striga control had the objective of determining the ability of a new striga seed germinator GR7 - to germinate striga seed in Samaru soils. The time necessary for a response and the relationship between dosage and response were studied. The interactions with nitrogen were also studied.

Objective

To test the efficacy of strigol derivatives (germinators) in controlling heavy striga infestations in sorghum and maize without having to resort to fallowing. The experiment was laid out as a $2^2 \times 4$ factorial design in 4 randomized replications as follows:

Maize vs Sorghum

x

Nitrogen 25 kg/ha vs Nitrogen 125 kg/ha

x

GR7 at dosages of 0, 0.2, 0.4 and 0.8 kg a.i./ha

The effect of the above variables on grain yield, total dry shoot weight and striga emergence was determined in order to:

a) evaluate GR7 for striga control

b) find that combination of GR7 and fertilizer nitrogen giving highest grain yields and lowest striga populations at harvest.

1. Nitrogen was in the form Calcium Ammonium Nitrate (26%N) applied as a basal 25 kg N/ha during seedbed preparation. The higher rate (100 kg/ha) was applied at the end of July.

2. GR7 germinator was applied with a 'herbispray' one week before planting and incorporated with one pass of a Boyd rotary cultivator.

Field operations

May 30th	- GR7 treatments applied
June 6th	- Maize (S123) and sorghum (1499) planted
June 8th	- Atrazine and paraquat applied on all plots
June 24th	- Thinning on maize and sorghum started
July 6th	- Basal application of nitrochalk
July 14th	- Application of endosulfan insecticide
July 29th	- 100 kg N/ha applied to high N treatment plots
Oct. 4th	- Maize harvested
Dec. 7th	- Sorghum harvested

1. Maize

In the presence of the higher N application, the maize yields increased and striga emergence progressively decreased in reponse to increasing levels of the GR7. This means that GR7 must have been actively germinating striga seed, a large percentage of which died without effectively parasitising the maize roots. The percentage mortality increased with the level of germinator. Unsuccessful parasitism is attributed the effect of high tissue nitrogen in reducing parasitism (Parker 1965). High N alone could have caused an increase in emergence because increased crop vigour could have supported more emerged striga. (Last 1960; Parker 1965) see also Table H.III 41.

The high N was applied on July 29th, over nine weeks after GR7 was applied. The high N effect must therefore have occured nine weeks after application, indicating that GR7 was persistent and active in the soil for that length of time.

Any mortality occuring during the nine week period would have been caused by seed germinationwhich took place before the maize was old enough to provide attachment sites, causing the death of those seeds from exhaustion.

2. Sorghum.

The pattern of response to higher nitrogen and GR7 applications is similar to that of maize, though modified by the longer period of growth of the sorghum after the higher nitrogen application. This resulted in a considerable increase in sorghum grain yield with 0.4 units of germinator at both levels of nitrogen application.

3. Germinator performance.

The increased emergences of striga in the a sence of higher N presented in Table H.III 45 are minimum estimates of the increased striga germination under ground which must have occured after the 29th July. It will be noted that there was very little further germination of striga on maize in the absence of germinator. This tends to confirm the hypothesis that maize at Samaru stops exudate production early in its life cycle. In contrast, at least 26% of the total emergence on the sorghum occured after July 29th. The success of the lowest dosage in germinating at least 120% more striga in the presence of an actively exuding sorghum crop is remarkable when the figures intable H.III 45 indicate that at least 86% must have germinated after July 29.

The reduced or negative response in sorghum vigour at the highest dosage might be attributed to either a direct toxic effect or an indirect effect of the germinator. The data in Table H.III 46 support the latter,

Table H.III 39
Effect of Nitrogen and Germinators
on maize grain yields (kg/ha)[1]

(treatment means)

erminator rate (kg/ha)	25 kg/ha N	25 kg/ha N
0.0	3108	2833(0.290)
0.2	1643(0.005)	2776(0.250)
0.4	1824(0.010)	3146(0.460)
0.8	1994(0.020)	3429(0.260)

[1] Values in brackets quote the exact significance of the difference from the 'no-germinator - low-nitrogen' check.

Table H.III 40
Effect of Nitrogen and Germinators
on Total Striga Count (1000s/ha)[1]
at Harvest - Maize

(treatment means)

Germinator rate (kg/ha)	25 kg/ha N	125 kg/ha N
0.0	7.08	5.48(0.430)
0.2	26.34(0.040)	2.27(0.350)
0.4	14.82(0.210)	3.97(0.370)
0.8	13.79(0.250)	1.70(0.290)

[1] Values in brackets quote the exact significance of the difference from the 'no-germinator - low-nitrogen' check.

Table H.III 41
Effect of Nitrogen and Germinators
on Mature Striga Count (1000s/ha)
at Harvest - Maize

(treatment means)

Germinator rate (kg/ha)	25 kg/ha N	125 kg/ha N
0.0	1.23	1.60(0.410)
0.2	8.03(0.005)	1.13(0.480)
0.4	2.08(0.300)	0.28(0.280)
0.8	4.82(0.025)	0.19(0.260)

[1] Values in brackets quote the exact significance of the difference from the 'no-germinator - low-nitrogen' check.

Table H.III 42
Effect of Nitrogen and Germinators
on Grain Weight of Sorghum (kg/ha)
at Harvest [1]

(treatment means)

Germinator rate (kg/ha)	25 kg/ha N	125 kg/ha N
0.0	1250	1436(0.261)
0.2	1095(0.305)	1062(0.027)
0.4	1741(0.056)	1949(0.015)
0.8	1367(0.349)	1265(0.480)

[1] Values in brackets quote the exact significance of the difference from the 'no-germinator - low-nitrogen' check.

Table H.III 43
Effect of Nitrogen and Germinators
on Total Striga Counts (1000s/ha)
at Harvest - Sorghum[1]

(treatment means)

Germinator rate (kg/ha)	25 kg/ha N	125 kg/ha N
0.0	79.5	58.5(0.236)
0.2	175.2(0.005)	106.7(0.181)
0.4	66.4(0.339)	28.9(0.046)
0.8	64.3(0.328)	40.2(0.092)

[1] Values in brackets quote the exact significance of the difference from the 'no-germinator - low-nitrogen' check.

Table H.III 44
Effect of Nitrogen and Germinators
on Mature Striga Count (1000s/ha) at
Harvest - Sorghum[1]

(treatment means)

Germinator rate (kg/ha)	25 kg/ha N	125 kg/ha N
0.0	34.6	23.0(0.330)
0.2	116.7(0.005)	63.0(0.147)
0.4	29.1(0.410)	10.5(0.811)
0.8	36.1(0.482)	15.8(0.243)

[1] Values in brackets quote the exact significance of the difference from the 'no-germinator - low-nitrogen' check.

Table H.III 45
Additional striga emergence after 29/7
in the absence of higher fertiliser N(1000s/ha)

Germinator rate	Maize 29/7 – 4/10	Sorghum 29/7 – 7/12
0.0	1.60(0.430)	20.96(0.248)
0.2	24.07(0.007)	68.50(0.025)
0.4	10.85(0.121)	37.49(0.123)
0.8	12.09(0.097)	6.08(0.414)

Table H.III 46
Mean Maize Vigor Rating and Striga Abundance Rating as affected by treatment

Germinator dosage (GR45)	BUTYLATE		NO BUTYLATE	
	Crop vigor Rating*	Striga Abundance Rating**	Crop vigor Rating*	Striga Abundance Rating**
0.0	6.75	5.50	5.50	7.00
0.1	6.75	3.75	5.75	6.75
0.2	5.75	4.00	5.00	6.50
0.4	8.25	4.24	4.75	8.00
Ethepon	7.50	4.50	5.75	7.25
Mean	7.00	4.40	5.35	6.90

* 9 = highest vigor; 5 = vigor loss, striga symptoms; 0 = no plant.

** 9 = 80 – 100% striga cover; 5 = 50% striga cover; 0 = no striga.

hypothesis. It is probable that germinator activity continued well into the drying cycle in September at this dosage causing a heavy underground infestation which would result in reduced crop vigour but would occur too late to increase striga emergence.

Conclusions.

1. A dose of as low as 0.2 units of GR7 was shown to be actively germinating striga for at least 59 days after application.

2. A dosage 0.8 units is apparently not toxic to sorghum or maize and was probably still actively germinating striga in September.

3. An application of 0.4 units combined with 125 kg N/ha gave the highest yield and lowest striga count in maize.

4. An application 0.4 units combined with 125 kg N/ha gave the highest yield and lowest striga count in sorghum. The increased grain yield in the presence of high N was 453 kg/ha worth ₦91.01 at 1977-8 prices. This leads to a 'break-even' price of ₦227.52 for 1 kg of GR7. The bulk production price is expected to be fraction of this.

1978-9 season.

Herbicides are being combined with germinators to kill germinating striga. Table H.III-46 shows that the use of butylate alone gave some increase in crop vigour while the use of a combination of butylate and GR 45 (a cheaper analogue of GR7) gave striking increases in crop vigour and striga control. This is a promising potential use for striga germinators in addition to the most logical method of applying them to germinate striga in the absence of a susceptible host crop.

Sub-programme H.III 3/4 viii

Experiment BQ 94 (77) - Integrated Striga Control - KOZA

Objective:

To measure the effect of rates of striga germinator material GR7 x fertilisers on millet and cowpea yields and on striga survival.

Field Operations:

Were not carried out correctly. Table 48 shows the treatments which were applied.

Results

Table 48 shows that on September 12, the 0.8 kg/ha rate of GR7 and the 125 kg/ha N treatment with no germinator significantly increased flowering striga counts. This effect did not appear on the 19th subsequent weeks. No conclusions on optimum rates can be made from this experiment.

Table H.III 48

KOZA - Effect of Germinators and Nitrogen on Flowering Striga Counts on 12/9/77 and 19/9/77 (1000s/ha)

(treatment means)

Germinator Rate kg/ha	12/9	19/9
0.2	0.629 (0.180)	2.597 (0.390)
0.4	0.866 (0.390)	2.597 (0.390)
0.8	1.652 (0.040)	2.990 (0.170)
0.0 + 125 kg/ha N	1.615 (0.025)	2.638 (0.340)
0.0 + basal N	0.973	2.439

1. Values in brackets quote the exact significance of the difference from the check.

H.III 3/4.1 viii

Experiment AM 330(77) - Striga germinators. Time of application.

Objective: To find the minimum optimum period for applying striga germinators prior to sowing of Maize.

Treatment

GR7 at 0.8 kg ai/ha
vs
GR28 at 0.8 kg ai/ha
x
Applied at sowing
vs
2 days before sowing
vs
4 days before sowing
vs
8 days before sowing
(plus a no germinator check)

Field Operations

June 20	-	Germinators (8 days preplant) applied with VLV.
June 24	-	Germinators 4 days preplant applied.
June 26	-	" 2 days " "
June 28	-	Maize drilled on 2.5 ft. ridges to give a population of 20,505/ha and germinators applied.
August 25	-	Calcium ammonium nitrate 200.47 kg/ha side-banded
October 10	-	Harvesting of striga and maize.

The late sowing date in this trial enforced by the late arrival of the GR28 germinator resulted in a poor and uneven stand as a consequence of a drought in July.

Table H.III 45

Effect of Time of Application of Germinators on Maize Grain Yield (kg/ha)[1]

(treatment mean)

Days before sowing	GR7	GR28	Mean
0	492(0.143)	692(0.006)	592(0.010)
2	278(0.104)	337(0.255)	308(0.110)
4	782(0.002)	568(0.082)	675(0.002)
8	720(0.004)	461(0.230)	590(0.010)
Mean	568(0.005)	514(0.030)	
Check (no germinator applied)	395		

[1] Values in brackets quote the exact significance of the difference from the check.

Table H.III 46

Effect pf Time of Application of Germinators on Total Emerged Striga at Harvest (1000s/ha)[1]

(treatment means)

Days before sowing	GR7	GR28	Mean
0	17.77(0.240)	16.40(0.320)	17.09 (0.220)
2	4.785(0.080)	12.99(0.450)	8.886(0.150)
4	16.40(0.320)	13.67(0.500)	15.04 (0.380)
8	14.35(0.450)	7.519(0.150)	10.93 (0.270)
Mean	13.33(0.450)	12.64(0.390)	

[1] Values in brackets quote the exact significance of the difference from the check.

Table H.III 47

Effect of Time of Application of Germinators on Mature Striga Count at Harvest (1000s/ha)

(treatment means)

Days before sowing	GR7	GR28	Mean
0	0.492(0.020)	3.609(0.300)	2.050(0.040)
2	1.367(0.020)	4.101(0.420)	2.734(0.060)
4	2.242(0.090)	1.367(0.020)	1.805(0.020)
8	5.467(0.160)	1.859(0.060)	3.663(0.240)
Mean	2.392(0.030)	2.734(0.040)	
Check (no germinator applied)	4.333		

[1] Values in bracket quote the exact significance of the difference from the check.

Results

Mature striga at harvest (Table 47) and grain yield (Table 45) showed marked treatment effects. Total striga at harvest (Table 46) differed little under treatment.

The optimum interval before sowing, in terms of increased yields and decreased mature striga was 4 days for both germinators.

Both GR7 and GR28 significantly increased mean grain yield ($P = 0.005$ GR7 and $P = 0.030$ GR28) at all dates.

GR7 applied 8 days preplant gave very much more mature striga and total striga at harvest, than GR28 at 8 days preplant. This would indicate that GR7 was more persistant than GR28.

Conclusions -

Both germinators increased maize grain yield but the poor stand in this experiment makes it difficult to compare GR7 and GR28. The very long period of persistance of GR7 demonstrated in the main striga germinator trial at Samaru means that the times of application in this trial were far too close to the planting date to demonstrate meaningful differences.

Sub project H.III 3/4.2 v

EFFECT OF TIME AND TYPE OF DRY SEASON CULTIVATION ON SPEARGRASS REGROWTH.

Researcher S.T. Lagoke

The first set of cultivation in this experiment was conducted on January 12, 1976. Details of further cultivation are reported on the table. During the last season, each strip was further divided into plots for the purpose of cropping.

Blanket application of paraquate was done twice before cropping. Only vefetative weights of crop were available. Speargrass regrowth at 2 years and 1 month after the first series of cultivation are shown on table H.III 48.

Results

Dry season cultivation with single bottom furrow disc plough still remained the most effective treatment against speargrass. With an additional secondary disc harrow, it was more effective than other types of cultivation with three or more cultivations. The repeatability of this treatment was further proven by the cultivations done on 12/1/77. Disc-plough without an additional cultivation was more effective than many other treatments.

In conclusion, trials are being conducted to investigate the appropriate time of cultivation and the persistence of the treatment over a number of years. It however needs be emphasized that double disc-plough did not produce the desired depth of cultivation - 25 cm, hence the degree of control, in the dry season.

Table H.III 48

	Speargrass dry matter production x 1.07 = kg/ha.
Disc-plough on 12/1/76 + Disc-harrow at 399 days later	44
Chisel plough on 12/1/76 + 4 disc-harrow at 137, 66, 162, and 80 days intervals	56
Disc plough on 28/5/76 + 3 Disc-harrows at 66, 135, 80 days intervals	122
Chisel plough on 28/5/76 + 3 Disc-harrows at 66, 162 and 59 days intervals	103
Rotavator on 28/5/76 + 2 Rotavations at 153 and 105 days intervals.	105
Underbuster on 28/5/76 + 2 underbustings at 153 and 104 days intervals	48
Disc-ploughing on 12/1/77	78
Chisel plough on 12/1/77	181
Rotavator on 12/1/77	189
Underbuster on 12/1/77	131
Control	204

Sub project H.III 3/4.2 iv

CHEMICAL CONTROL SPEARGRASS

SITE: MOKWA

Glyphosate was applied on actively growing speargrass foliage in the dry season, either in high volume (300 l/ha) very low volume (20 l/ha). 2% wetter was added to low volume application. Glyphosate at 0.75, 1.0 and 1.50 kg ai/ha were either split-applied at 2 weeks after the first application or at 50% regrowth. The table H.III 49 shows speargrass fresh weight at 45 weeks after application without any post-spraying cultivation.

Generally very low volume application were more effective on speargrass than their corresponding rates in high volume. Speargrass was effectively controlled by those treatments with initial application of 0.75 kg ai/ha glyphosate with a follow-up application of 0.25, 0.50 or 0.75 kg either at 2 weeks after the initial application or at 50% regrowth. Follow-up application at 50% regrowth was more effective than at 2 weeks after initial treatment. When 1 kg ae/ha was equally split (0.5 + 0.5) with a second application done at 50% regrowth, it gave the most effective speargrass control.

Table H.III 49

EFFECT OF GLYPHOSATE ON SPEARGRASS REGROWTH (FRESH WT. x 20 kg/ha)

Glyphosate kg ai/ha	Applied Once		SECOND APPLICATION			
			At 2 weeks		At 50% regrowth.	
	Fresh wt.	% regrowth	Fresh wt.	% regrowth	Fresh wt.	% regrowth
0.5 + 0.5 (ULV)	-	-	76	20.7	52	14.1
0.75 + 0.75 (ULV)	-	-	43	11.7	23	6.4
0.5 + 0.25 (ULV)	-	-	229	62.2	54	14.7
0.75 + 0.50 (ULV)	-	-	29	7.9	25	6.8
0.75 + 0.25 (ULV)	-	-	106	28.8	49	13.3
0.50 (ULV)	174	47.3	-	-	-	-
0.75 (ULV)	155	42.1	-	-	-	-
0.75 + 0.1% Wetter (HV)	352	95.7	-	-	-	-
1.00 (HV	222	60.3	-	-	-	-
1.50 (HV)	159	43.2	-	-	-	-
Control	368	100	-	-	-	-

CHEMICAL CONTROL OF SPEARGRASS

SITE: MOKWA

Actively growing speargrass was sprayed with glyphosate in either very low volume, (20 l/ha) (ULV) plus 2% Agral or high volume 300 l/ha (HV) plus 0.4% Agral on 7/12/77. Two blocks were slashed at 3 weeks after application.

At 10 weeks after application, glyphosate in ULV was about four times more effective than its application in HV. With the ULV application, there was no advantage in exceeding 1 kg ai/ha glyphosate while about 3 kg ai/ha glyphosate would be required to produce the desired control

Table H.III 50

EFFECT OF DRY SEASON APPLICATION OF GLYPHOSATE ON SPEARGRASS

kg ai/ha	Very low volume		High volume	
	% control (scorching)	% regrowth on slashed plots	% control (Scorching)	% regrowth on slashed plots
Glyphosate 0.5	70.0	7.41	-	-
Glyphosate at 0.75	82.5	3.70	-	-
Glyphosate at 1.00	95.0	0.00	-	-
Glyphosate at 1.50	95.0	3.70	57.5	7.41
Glyphosate at 2.00	-	-	70.0	7.41
Glyphosate at 3.00	-	-	95.0	3.70
Glyphosate at 4.00	-	-	90.0	3.70
Control	-	-	0.0	100.00

ISN - 34556
PID-AAB-975

REPORT TO THE BOARD OF GOVERNORS ON THE INSTITUTE'S WORK IN 1976-77

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FARM SYSTEMS AND INTERCROPPING PROGRAMME

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FARM SYSTEMS AND INTERCROPPING PROGRAMME

CONTENTS :

Review		Page	i
List of participants		-	viii
Intercropping			
1.1	Mixtures of Cereals	-	1
1.2	Mixtures involving groundnuts	-	22
1.3	Cereals / Cowpea	-	30
1.4	Cotton / Cowpea / Cereals	-	32
1.5	Cotton and Cereals	-	36
1.6	Maize, Soybean, Cowpea	-	39
	Remaining State trials	-	41
	Maize: Sorghum: Yam: Cowpea	-	43
	Cereals, groundnuts sown "gicci", together with cowpea	-	48
	Rotations and Sequences	-	50
H III	Weed Control and Tillage		
	Introduction	-	53
1.	Weed control in the hoe farming system	-	53
2.	Weed control in animal powered systems	-	66
3.	Mechanised weed control		
3/1	Partial mechanisation	-	69
3/2	Fully mechanised weed control	-	76
4/1	Control of Striga hermonthica by foliar active herbicides	-	77
4/3	Integrated striga control in mixed crops	-	78
4/2	Eradication of Imperata cylindrica with herbicides		79
4/4	Eradication of Imperata cylindrica by cultivation		80
5.	Weed control in Irrigated areas		
5/1	Selective weed control in crops	-	91
5/2	Integrated control of Cyperus spp.	-	103

Review

A. Intercropping:

During the year some 13 experiments were done at Samaru on the subject of intercropping. These were in addition to extensive trials at State locations within the Northern States. Experiments can be grouped into the four categories listed below:

i) Mixtures involving cereals only

ii) Mixtures involving cereals and legumes

iii) Mixtures involving cereals and cotton

iv) Mixtures designed to investigate plant competition effects of plant population change.

i). Mixtures involving cereals only:

Work under this head has involved three series of experiments carried out during the three year period 1974-76. These have been completed and the work written up and submitted for publication.

The first series of experiments involved all combinations of pairs from six crops: ex-Ghana, ex-Borno millets; Bomo local, Samaru 123, O 96 maize varieties, and Short Kaura 5912 sorghum. Comparisons of yield differences between crops grown in mixture and the yield of those crops grown sole produced a clear relationship between total yield gain from the mixture and difference in age at harvest.

Total yield gain, expressed as "Reciprocity" (R), as defined by:

$R = ((\frac{Y_{ij}}{Y_{ii}} + \frac{Y_{ji}}{Y_{jj}})/2) - 1$, where Y_{ij} is the yield of crop i in mixture with crop j, Y_{ii} is the sole crop yield of crop i; Y_{ji} and Y_{jj} are equivalent yields for crop j. This relationship was: $R = .009 - .00268822D + .00005733D^2$, where D = difference in days to harvest, and accounted for 83% of the variation in yield gain due to mixing.

The relationship indicated that gain will be obtained when there are at least 43 days between harvest dates.

Similarly, the correlation between accumulated excess in height of one cereal over the other in the mixture and gain in yield was highly significant. (excess in height = difference between the integrals of $(f)h_{ij}$ and $(f)h_{ji}$, where $(f)h_{ij}$ is the calculated curve for height with time for cereal i, and $(f)h_{ji}$ that for the other cereal. As an example the correlation for ex-Ghana millet was .9456, significant at .015 prob. with only 3 d.f.).

The second series was designed to investigate the effects of differences in height more completely. This experiment consisted of combinations of all pairs from seven sorghum varieties chosen to mature at the same time, but at different heights, or at approximately the same height but at different times. Percentage gain in yield in the mixture was highly significantly related to both height and age differences.

$\frac{100Y_{ij}}{Y_{ii}} = 93.5 + .1096H + .1274D$, and showed that yield of sorghum in a mixture will gain provided that height at harvest differs by more than .59m and age by more than 51 days.

These series of experiments have demonstrated that cereal yields in mixture will be higher than those in equivalent sole crops provided there is reduced interference between plants during their reproductive phase either because the upper part of the canopy, known to contribute most to grain production is higher than an associated plant, or because the other plant is not there during the 40-50 days from ear/head initiation to grain maturity.

Thus the subsistence farmer has a sound physiological basis for mixing millet and sorghum.

The last series of experiments was with selected 3-crop mixtures of millet, maize and sorghum and demonstrated that maize can

be incorporated into the farmers' millet sorghum mixture without loss of yield, and allowing a greater spread of grain harvest than the two at present.

Finally, these trials, carried out under fertility levels considerably higher than those normally used by farmers, have demonstrated that there can be no justification for persuading farmers to change to sole cropping, as the level of technology is raised, on the grounds that yields from sole crops will be higher.

ii) Mixtures involving cereals and legumes:

There were two series of experiments under this heading. The first, investigating the "gicci" system of cultivation with cereals and groundnuts, carried out during the three years 1974-1976 has been completed, written up, and accepted for publication. The second series, with cereals and cowpea, is now in the second year of experimentation.

Investigations with the gicci system, which involves sowing cereals at wide spacing and sowing another crop later within the established cereal, in this case groundnuts, have demonstrated that a 27% cash gain was obtained on average overall three years of the experiment when compared with sole groundnuts. Not only have these experiments demonstrated the profitability of the system, but also that the system can be improved by increasing the density of cereal and by adding maize to the, usual, millet and sorghum.

Gross profit over sole groundnuts with widely spaced cereals was 15.6%, with closely spaced cereals was 39.4%. Gross profit from the 3-cereal mixture at close spacing was 53.7%.

The second series, with cereals and cowpea, considered the effects on cowpea yield of intersowing cowpea under established stands of three maize varieties of differing times to maturity. Results from the first year, 1976, of the experiment are quite exciting. Yield of cowpea, from all eight varieties tested is highly correlated with length of growing period of maize, and two cowpea varieties, both local (var.2479 and var.1696) gave yields of 1381 and 1859 kg/ha^{-1} respectively in addition to 4286 kg/ha^{-1} of grain from Upper Volta Early maize. The exciting fact was that this variety of maize was harvested before the cowpea began flowering and that no insect control measures by spraying were taken. If this result can be repeated then, clearly, some mechanism is operating which, when cowpea is grown within maize prior to flowering, is imbuing some resistance to attack by insects.

iii) Mixtures involving cereals and cotton

These experiments, investigating sowing date of cotton within cereals and sole, and growing period of cereal, have been completed, written up, and accepted for publication. Results indicated that cereal yields were not affected by the presence of cotton but that cotton yields were reduced by both delayed sowing and presence of a cereal.

Both cotton height and number of sympodia produced were affected by delayed sowing and by intersowing. However, sowing cotton early, preferably at the same time as the cereal, allowed cotton to produce a frame comparable with that of sole cotton, and a cotton yield proportional to that frame. Although cotton yields were reduced by intersowing with cereal, even when sow. at the same time as the cereal, gross cash returns were considerably higher from the mixture, particularly when maize was

the cereal. Mean cash return from sole cotton sown at the beginning of June was ₦704, and from sole maize sown at the same time was ₦797. Mean cash return from the mixture of cotton and maize sown at the beginning of June was ₦827, 17.5% more than sole cotton and 3.6% greater than sole maize. The mixture, when cotton was undersown three weeks later, gave a cash return of ₦998, 41.8% greater than early sown cotton and 297.9% higher than sole cotton sown three weeks late.

Thus, cotton farmers, who delay sowing of cotton because of other operations on cereals, would be better advised to sow cotton early, within the cereal.

iv) Mixtures investigating plant competition and population

There are four series of experiments, two of which have been initiated in 1977. Both are systematic designs, the first attempting to determine that part of a plant which causes interference with growth and yield of neighbouring plants. This trial involves different varieties of maize. The second investigates continuously changing populations of cowpea and maize, both mixed and sole.

The first two series are now in their third and second year of experimentation respectively. The first attempts to determine optimum populations for cereals within mixtures as a function of difference in time to maturity. Results are as yet unclear but indicate that in a mixture of maize and Short Kaura sorghum, where maize is the taller of the two crops, then maize population should be raised by approximately one-third to optimise cash return. Population of sorghum should not change from the normal sole crop population.

The second experiment approached the problem from a different angle by utilising the linear relationship between cereal yield per plant and population change. Thus an "optimum" population can be calculated from the linear equation for maize within a mixture and grown sole. It was found that the ratio between the theoretically calculated "optimum" population and the actual population was very significantly correlated with ear height of the maize variety used, in mixture with Short Kaura sorghum.

Population theoretical = .13 + .79H, where H = ear height measured from maize at the normally accepted optimum population (47000/ha) for sole maize. ($r = .9468$, sig. at .01 prob; $r^2 = .8964$).

This relationship can be combined with the age to maturity of the maize varieties to give the following formula:

$$P_1 = \frac{2M_2(.13 + .79H) - M_2P_2}{M_1}$$

where M_1 and M_2 are the days to maturity of the two crops in the mixture, and P_2 the population of sorghum.

Thus, knowing the age to maturity of the maize variety, and the ear height, it is possible to calculate the proportion of sole crop population that population should be raised to optimise yield. Although this is but a first measure it is logical that the higher the ear is in relation to the sorghum canopy, and the longer that situation prevails, then the more light is available for grain yield per plant, and the higher the population should be to optimise yield per unit area.

The intercropping work described in this report was begun in 1974 and results have demonstrated that the Nigerian subsistence farmer has been correct to resist conversion to sole cropping. There are advantages to sole cropping, not the least being the ability to mechanise and thus cultivate large areas of land, and that it is more practicable to apply various protection regimes. However, the major disadvantages of sole cropping are the inability to utilise the rains efficiently, and that it is not possible to maintain a legume on the ground continuously. The overlapping intercropping practised by the subsistence farmer adds at least a month to the growing season, permits flexibility in choice of crops, and allows continuous legume cover.

The next phase in intercropping research must be to attempt integration of the main mixtures into a system which, if not completely self-sustaining, will reduce the need for expensive inputs. It is required to:

a) develop ideotypes of cereal suitable for mixtures because reproductive phases do not overlap, either in space or time.

b) Investigate the value of rotating legumes within mixtures for maintaining fertility with reduced fertiliser inputs.

c) Investigate insect pest and disease relationships within mixtures, particularly for those crops which are very susceptible to attack when grown sole.

d) Study aspects of inter-specific and varietal competition with the aim of reducing inefficient use of environmental resources.

CROPPING SYSTEMS PROGRAMME

This programme, as in past years, will be reported in three sections: Intercropping, Rotations and Sequences, Weed control and tillage. A list of those who have participated in the programme during 1976 is given below.

Dr. A. Abdullahi	.. ..	Director
Dr. E. Asemime	.. ..	Lecturer, Agronomy Department
Mr. A. H. Choudhary	..	Research Fellow, Weed Science
Dr. P. M. Egharevba	..	Research Fellow, Agronomy
Mr. S. Lagoke	.. ..	Research Fellow, Weed Science
Malam Y. Yusuf	.. ..	Research Fellow, Agronomy
Mr. W. Ndahi	.. ..	Assistant Research Fellow, Weed Science
Dr. L. Nnadi	.. ..	Research Fellow, Soil Science
Mr. J. E. Ogborn	.. ..	Senior Research Fellow, Weed Science
Dr. A. K. Raheja	.. ..	Senior Research Fellow, Entomology
Mr. E. F. I. Baker	..	Convenor

....

Mixtures of Cereals

1.1 An experiment comparing yields from mixtures of all pairs of six cereals with sole crop yields has now been done at Samaru for the three years 1974-1976. Each experiment used three replications of a split-block design in which different cereals formed both rows and columns. "Row" cereals were sown on odd numbered ridges, "column" cereals on even numbered ridges. This gave two replicates of each cereal mixture in each block and one replicate (the leading diagonal before randomisation) of each sole crop. Analysis was simplified by harvesting odd and even numbered ridges separately to give two yield estimates for each plot, including sole crops.

Both the 1974 and 1975 experiments were given basal dressings of 300 kg. compound 20:10:10 ha^{-1} whilst in 1976 the basal dressing was increased to 800 kg. ha^{-1}.

Each cereal was analysed separately in each year and over all years; yields are given in Table A1 to Table A6.

Table A1

Yields of Ex-Ghana Millet in kg. grain @ 14% gr. ha^{-1}

Grown with	1974	1975	1976	Mean
Ex Borno	1789	1225	1854	1623
B. Local	1788	1052	1857	1566
S. 123	1937	1157	1714	1603
096	2054	1214	1747	1672
S.K.	2366	1274	2200	1947
SOLE	1923	1125	2053	1700
S.e. Single Plot±	225.7	168.8	315.8	248.9

Although there was no difference in any year between yield of sole crop ex Ghana and the mean of mixed ex Ghana, ex Ghana grown with Short Kaura was never lower than the sole crop, being significantly greater in 1974, nor was the yield of mixed ex Ghana ever significantly worse than the sole crop yield.

Table. A2.

Yield of ex Borno millet in kg. grain @ 14% mo. ha^{-1}

Grown with	1974	1975	1976	Mean
Ex Ghana	2352	1226	2061	1880
B. Local	2283	1250	2246	1926
S. 123	2042	1091	1925	1686
096	2286	1186	2154	1875
S.K.	2617	1212	2878	2236*
SOLE	2239	1130	2309	1893
S.e. single plot ±	± 279.1	±180.2	236.6	192.7

Ex Borno grown with short kaura sorghum always outyielded sole crop ex Borno, significantly so in 1974, 1976, and overall. When grown mixed with S. 123 maize ex Borno was significantly outyielded by the sole crop. In no other mixture was there a difference in yield between sole and mixed ex Borno millet.

Table A3

Yield of Bomo local maize in kg. grain @ 14% mo. ha^{-1}

Grown with	1974	1975	1976	Mean
Ex Ghana	3530	2924	5188	3881
Ex Bomo	2786	2794	5321	3634
S. 123	3047	3154	4714	3638
096	3060	3095	5428	3861
S.K.	3781	3157	6179	4316
SOLE	3170	3157	5792	4040
S.e. single plot ±	334.5	591.5	1088.9	764.8

Bomo local did not gain significantly in yield over all years when grown with any other crop, though there was a clear trend to yield better with short kaura than other cereals.

Table A4

Yield of Samaru 123 maize in kg. grain @ 14% m.c. ha^{-1}

Grown with	1974	1975	1976	Mean
Ex Ghana	4738	2569	6582	4646
Ex Bornu	4982	2217	7295	4831
B. Local	4475	3239	6072	4595
096	4374	2801	6758	4645
S.K.	5976	2764	7389	5375
SOLE	4841	3317	6833	4830
S.e. single plot	526.1	634.9	1646.7	1103.8

Samaru 123 maize showed no difference in yield between sole crop and when mixed overall years. A significant gain was made in 1974, when grown with short kaura, and a loss in 1975 when grown with ex Bornu.

Table A5

Yield of 096 maize in kg. grain @ 14% m.c. ha^{-1}

Grown with	1974	1975	1976	Mean
Ex Ghana	3789	2551	5604	3981
Ex Bomo	3430	2736	6481	4216
B. Local	3553	3583	6141	4426
S. 123	3524	3081	6280	4295
S.K.	3770	2869	6911	4517
SOLE	3457	3337	5775	4190
S.e. single plot +	654.9	698.9	1223.0	918.0

Yield of 096 maize was not affected by mixing with other cereals in any year, nor overall.

Table A6

Yield of short kaura sorghum in grain @ 14. m.c. ha^{-1}

Grown with	1974	1975	1976	Mean
Ex Ghana	3225	2857	3748	3275
Ex Bomo	3175	2565	3823	3188
Bomo local	3027	2857	3601	3162
S 123	2489	2436	3091	2672
096	2461	1847	3024	2444
SOLE	2827	2247	3418	2338
S.e. single plot	346.9	518.4	929.9	665.4

Although there was again a clear trend for short kaura to yield better when mixed with shorter season crops the individual yield differences were not significant.

Although, when analysing crops individually, it has been difficult to demonstrate significant gains from mixing no crop lost yield when mixed with another, except for the isolated example of Samaru 123 with ex Bomo in 1975. However, if yield in mixtures is expressed as a percentage of sole crop yields all crops can be combined for an overall analysis. When this is done a very clear relationship emerges between yield of crops when mixed and the number of days difference to maturity between the two crops concerned. This relationship accounted for 88% of the variation between mixture as is given below

$$\frac{1}{2}\left(\frac{X_{ij}}{X_{ii}} + \frac{X_{ji}}{X_{jj}}\right) = 100 - .2635\,D + .0057\,D^2$$

X_{ij} = Yield of crop i grown with crop j

X_{ii} = Yield of crop i grown sole

X_{ji} = Yield of crop j grown with crop i

X_{jj} = Yield of crop j grown sole

D = Days difference between harvest of crop i and j.

Gain in yield will be obtained when the difference in harvest dates is at least 48 days; the curve is given below.

Although the data is not given here, since it is not yet analysed, the difference in height of the crops also plays a considerable part in producing again and, as described later in the population experiments, particularly the height of the ear where maize is concerned.

These particular experiments will now be terminated, having been run for three years, whilst mixed variety trials are conducted at Sate locations. As an interim recommendation, the following can be used for cereal mixtures:

1. Choose crops with at least seven weeks difference in harvest dates (this can be done, as is practised by farmers, by sowing one cereal earlier than the other).
2. Choose a fast growing tall early cereal.
3. Choose a slow growing late cereal that is either dwarf or has two periods of fast growth (as short kaura sorghum).

1. 2. Mixed Sorghum Varieties

In the first series of experiments attempts were made to demonstrate the importance of differences in days between harvest as a criterion for choosing cereals for mixing. The premise being that an early variety which is taller than the later harvested crop makes better use of light; equally, the later crop has more light to utilise because of the removal of the first crop. In this series of experiments attempts have been made to estimate the relative importance of height at maturity and days difference to harvest, without being confounded by differences between species.

Seven varieties of sorghum were used, chosen so that they either matured at the same time, but at different height, or at approximately the same height, but at different times. The varieties were chosen so that their yield potentials were approximately the same, although it must be realised that it is not possible to be exact where either height or yield performance is concerned.

Varieties were:

R 960	Approx.	106	days	to	maturity	and	1.4m	tall
R 21	"	137	"	"	"	"	1.5	"
187	"	160	"	"	"	"	1.4	"
1412	"	160	"	"	"	"	1.6	"
181	"	160	"	"	"	"	1.8	"
SK 5912	"	160	"	"	"	"	2.5	"
FFBL	"	160	"	"	"			"

There was considerable variation in yield, and performance relative to each sole crop, between the two years of the experiment. Yields are given in Table 6 and 7.

An interim analysis, based upon annual means only, indicated that variation between mixtures accounted for 58% of total variation, whilst the linear component of the relation between height difference (at maturity of the earlier variety), days between harvest and yield relative to sole crop yield accounted for 74% of the variation between mixtures.

The relationship was

$$100 \left(\frac{X_{ij}}{X_{ii}}\right) = 92.8 + .1503 \ (\pm .0006)\ H + .1482(\pm .0093)\ D.$$

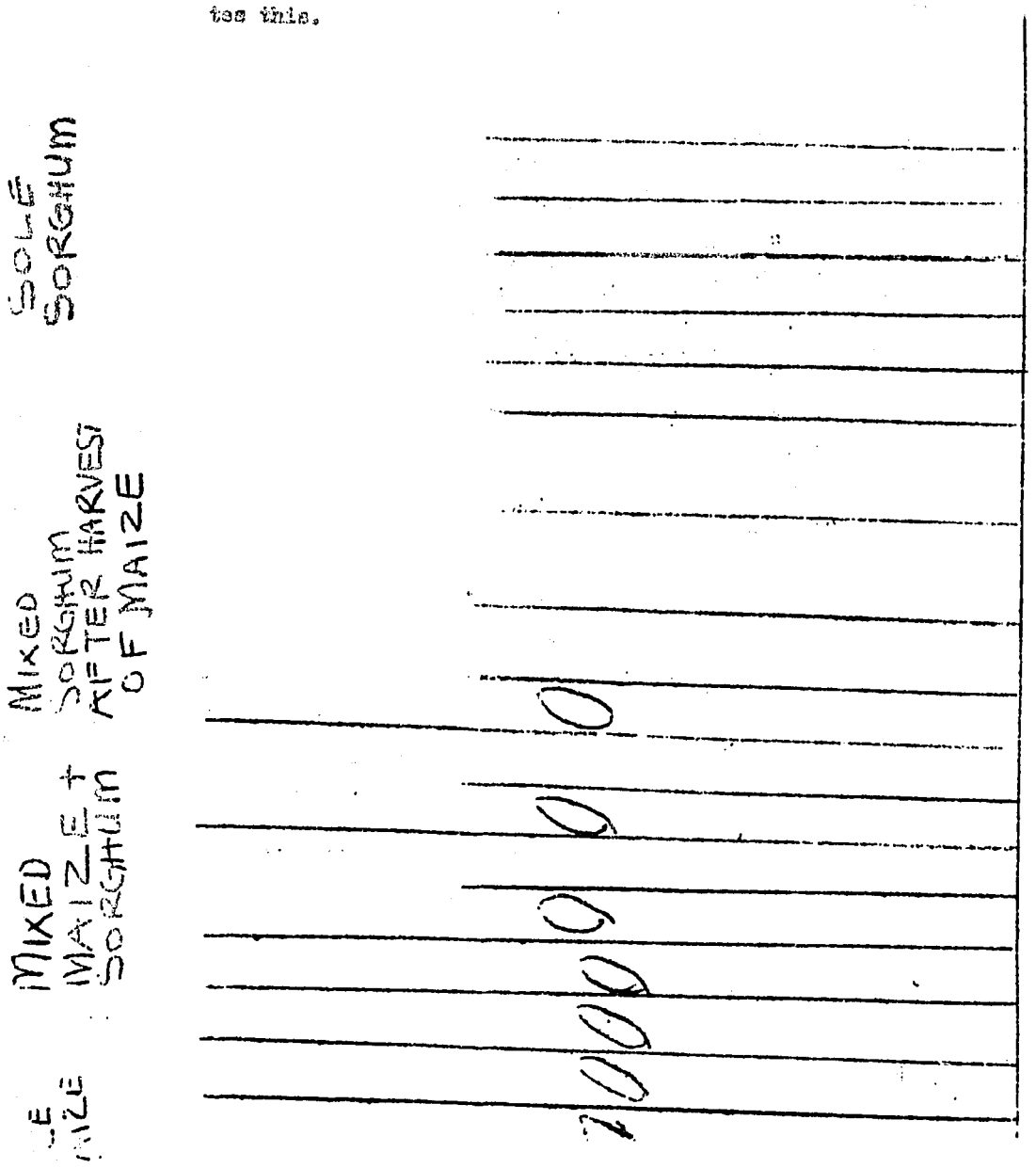
Table A7

Crop		Grown with						
		R 960	R 21	187	1412	181	SK5912	FFBL
R 960	1975	1134	1235	1566	638	1017	1090	549
	1976	1364	1258	1220	1270	1083	945	770
	Mean	1249	1247	1393	954	1050	1018	659
R 21	1975	1066	1101	1305	647	792	757	565
	1976	270	274	245	218	272	262	233
	Mean	668	687	775	432	532	509	399
187	1975	2294	1908	2506	1929	2396	1927	1162
	1976	1736	1576	1904	1466	1660	1449	1736
	Mean	2015	1742	2205	1698	2028	1688	1449
1412	1975	1659	1024	1647	1796	1611	1549	932
	1976	1483	1427	1221	1427	1562	1705	1134
	Mean	1571	1226	1434	1612	1586	1658	1033
181	1975	1662	1710	2374	1494	2341	1773	1129
	1976	1061	1113	1008	1356	1339	1243	774
	Mean	1361	1411	1691	1425	1840	1508	951
SK5912	1975	3201	2451	3482	2781	2352	2688	2334
	1976	2465	2751	2333	3027	3141	3081	2525
	Mean	2836	2601	2907	2904	2747	2884	2430
FFBL	1975	3463	3086	2971	2750	3826	3156	1977
	1976	2460	2889	2614	3172	2106	2775	2954
	Mean	2961	2988	2792	2961	2966	2966	2465

If height at maturity differs by more than .48m, and days between harvest differs by more than 48 days then the mixture will not yield less than equivalent sole crops. It is noticeable that the minimum period between harvests is the same as is the earlier experiments, and not coincidental that the time between heading and grain maturity is approximately 40 days. That is cereal mixtures should be so arranged that the part of the plant contributing to grain (above the ear in maize, or the upper canopy in sorghum and millet) should be free of competition for light during this period, either by being taller than the associated plant or by maturing later, and for both to gain from mixing it is clear that the earlier crop must be taller at heading than its associate.

1.3. These experiments have attempted to know why gain occurs from mixing cereals, by allowing better light penetration during the critical period for grain formation. To maximise the benefits from mixing consideration must be given to the number of plants present.

In the experiments so far described each crop was sown at a spacing which would have given an "optimum" plant population had they been grown sole. But, because one crop is taller or absent then each must be considered at lower than "optimum" population. The diagram below illustrates this.



There were two series of experiments, in both of which the objects were to relate plant population in mixtures to some characteristic of the crop or mixture so that, despite the empirical nature of any such relationship, recommendations could be simply formulated.

The experiments described earlier gave indications that gains from mixing were associated with differences in maturity dates and heights.

1.3.1 The first experiments, one to Mokwa in 1975, the other at Samaru in 1976 attempted to determine population of cereals in mixtures as a function of difference in time to maturity. For example, in a 1:1 mixture, that is where each cereal occupies the same area of land, where each cereal is being grown at the same spacing as is considered "optimum" for each as a sole crop then total plant population can be considered unity for the period to harvest of the earlier crop, and then half unity until harvest of the later crop. Thus, over the whole season "mean" population is:

$$\bar{P} = \frac{\frac{1}{2}M_1(P_1+P_2) + \frac{1}{2}P_2\,(M_2-M_1)}{M_2} = \frac{M_1P_1 + M_2P_2}{2M_2}.$$

where M_1 and M_2 are the times to harvest of each crop in days, and P_1 and P_2 are the proportions of sole crop optimum respectively.

For a 1:1 mixture of 0.96 maize and SK 5912 sorghum, with each sown at sole crop "optimum" spacing.

$$\bar{P} = \frac{120(1) + 160(1)}{320} = .875.$$

In these experiments treatments were determined by setting $P_1 = 1$ for five levels of P_2, $P_2 = 1$ for five levels of P_1 and the resultant 25 combinations arranged in a randomised block together with 5 sole crop populations for each crop.

Yield results are given in Table .A.8.....

Table A8

Yield in Kg. grain @ 14% m.c. ha^{-1} for maize and sorghum

Proportion of sorghum sole crop population			Proportion of maize sole crop population				
			.53	.80	1.06	1.33	1.60
.65	Maize	1975	2541	3564	4411	2941	3987
		1976	3706	4488	4998	4783	6052
		Mean	3124	4026	4705	3862	5020
	Sorghum	1975	984	972	1096	1146	1022
		1976	3337	2958	2347	3039	1981
		Mean	2161	1965	1722	2093	1501
.85	Maize	1975	2255	3414	4037	4760	3140
		1976	3502	4137	4148	4216	5372
		Mean	2879	3775	4093	4488	4256
	Sorghum	1975	1271	1196	1221	947	1171
		1976	4681	2469	2578	3242	2171
		Mean	2976	1833	1899	2095	1671
1.05	Maize	1975	2492	3688	4511	3364	3738
		1976	3003	4896	4590	5191	3570
		Mean	2748	4292	4551	4277	3654
	Sorghum	1975	1321	1445	1121	1420	1196
		1976	4138	2510	3405	2768	2958
		Mean	2729	1977	2263	2094	2077
1.25	Maize	1975	2517	3314	3788	3375	4087
		1976	2856	3842	5066	4386	3899
		Mean	2687	3578	4427	3881	3993
	Sorghum	1975	1844	1595	1246	1221	1196
		1976	2958	3744	3134	3066	2347
		Mean	2401	2670	2190	2144	1772
1.45	Maize	1975	2791	2642	3464	3941	3838
		1976	2754	3593	2663	3196	4601
		Mean	2773	3117	3064	3569	4220
	Sorghum	1975	1346	1371	1346	1246	1246
		1976	3989	3392	3392	2496	2808
		Mean	2667	2381	2369	1871	2027
Sole crop	Maize	1975	3159	3495	3420	3099	3121
		1976	3196	4040	4125	[illegible]	3961
		Mean	3178	3768	3773	[illegible]	3541
	Sorghum	1975	729	804	841	916	991
		1976	2835	3059	3100	2917	3493
		Mean	1782	1932	1970	1916	2242

Profit from the mixtures are given in Table. A9..

Naira Profit in Naira for maize sorghum mixtures at different population

Proportion of sorghum population	Proportion of maize population					Mean
	.53	.80	1.06	1.33	1.60	
.65	37.9	29.3	64.0	66.7	61.9	52.0
.85	106.5	-10.6	23.6	128.9	5.7	50.8
1.05	63.4	57.0	110.0	107.9	-7.6	66.1
1.25	22.0	65.3	89.8	74.4	-8.8	46.5
1.45	60.8	-13.3	-24.7	12.4	42.7	15.6
Mean	58.1	25.5	52.5	78.1	18.8	

(Maize @ N19.8; Sorghum @ N22.8 per 100 kg).

The experiments have not been analysed but inspection of mean profits above suggest that population of maize should be raised by about a third whilst maintaining sorghum at the same as sole crop. If this is done "mean" population for the mixture, as defined earlier, becomes unity.

3.2. The second experiment designed to investigate plant population of cereals in mixtures used that kg. yield per plant is linearly related to plant population. Thus the slope of the line can be calculated from two points, one from a low, the other from a high population. Once the slope of this line is known both optimum population and the yield expected at that population can be calculated.

The experiments compared six varieties of maize, grown sole and with short kaura sorghum, each at three plant population.

The varieties were:

Upper Volta early ..	Low ear height ..	80 days	to maturity
Bomo Local	Medium ear height,	90 "	" "
N.C. B.	" " "	100 "	" "
Biu Yellow	Low " "	105 "	" "
N.C.A.	High " "	115 "	" "
096	" " "	120 "	" "

Plant populations were 11900, 24000, 48000 plants $ha.^{-1}$.

Yields are given in Table A10.

Table A 11

Yield as kg. grain ha^{-1} at 14% m.c. and per plant for maize and sorghum (Yields as equivalent areas)

		11905 plant ha^{-1}				23809 plant ha^{-1}				47619 plants ha^{-1}			
		Maize		Sorghum		Maize		Sorghum		Maize		Sorghum	
		ha^{-1}	plant	ha^{-1}	plant	ha^{-1}	plant	ha^{-1}	plant	ha^{-1}	plant	ha^{-1}	plant
U.V.E.	Sole	1391	.117			2546	.107			4048	.085		
	Mixed	1687	.140	3156	.465	2814	.118	4398	.185	4740	.100	4495	.094
B.L.	Sole	1456	.122			2722	.114			4719	.099		
	Mixed	1385	.116	2368	.199	2728	.115	3685	.155	4805	.101	3966	.083
NCB	Sole	3467	.291			5336	.224			7532	.158		
	Mixed	3512	.295	2238	.188	5666	.238	3330	.140	8723	.183	4191	.088
B.Y.	Sole	3626	.305			6239	.262			8615	.181		
	Mixed	3577	.300	2297	.193	6185	.260	3524	.148	9134	.192	3834	.081
NCA	Sole	3577	.300			5833	.245			7792	.164		
	Mixed	3528	.296	2095	.176	5384	.226	3113	.131	8658	.182	3887	.082
096	Sole	3950	.332			6342	.266			8268	.174		
	Mixed	3425	.288	2274	.191	5714	.240	3487	.146	10303	.216	3226	.068
Sorghum Sole				2131	.179			3222	.135			3602	.076

Theoretical optimum population and yield for mixed and sole maize and sorghum are given in Table A 12

		Theoretical Population Plant ha.$^{-1}$	Theoretical Yield kg. grain ha.$^{-1}$
U.V.E.	Sole	112000	5367
	Mixed	105000	6043
	Sorghum	37500	5156
B.L.	Sole	171000	8226
	Mixed	258000	11526
	Sorghum	37500	4327
N C B	Sole	58000	7674
	Mixed	75000	9518
	Sorghum	38000	4266
B.Y.	Sole	68000	9138
	Mixed	80000	10248
	Sorghum	38000	4201
N C A	Sole	59000	7982
	Mixed	73000	9404
	Sorghum	45000	3915
C 9 6	Sole	55000	8374
	Mixed	124000	14477
	Sorghum	34500	3897
Sole Sorghum		38000	3876

There are always dangers in extrapolation from calculated data but for each maize, except Upper Volta Early, the plant population required to optimise yield was greater for mixed maize than for sole maize. Sorghum required no such change in population, giving a picture similar to the first experiments.

These maize varieties were also chosen because of differing ear heights. These were measured (from random ten plant samples) in each plot and are given in Table A 13.

Table A.13

Maize ear height, theoretical "mean" population, actual "mean" population.

Variety	Ear ht. (m)	P_t	P_a	$\frac{P_t}{P_a}$
U.V.E.	.71	.73	.75	.97
B.L.	1.03	.92	.78	1.18
N.C.B.	1.11	.90	.81	1.11
B.Y.	1.00	.89	.83	1.07
N.C.A.	1.08	1.04	.86	1.24
0.96	1.43	1.30	.88	1.48

P_a is, of course, correlated with days to maturity of maize, since sorghum remains constant. However, the ratio P_t/P_a does not remain unity, as would be expected if P_t was simply a reflection of maize age. Consequently, the correlation between P_t and ear height may have some real meaning. The ear height used for this correlation was measured from sole crops grown at 47000 plants ha^{-1}, the normally accepted optimum for sole maize. Even with the crude analysis given (on means above) the correlation coefficient was + .9468 (significant at less than .01% prob.) and gave:

$$P_t = .13 + .79H$$

Thus, knowing the age to maturity of the maize variety, and the ear height, it is simple to calculate the proportion by which sole crop population should be raised to optimise yield in a mixture with short kaura sorghum. The formula is:

$$P_1' = \frac{2M_2 (.13 + .79H) - M_2P_2}{M_1}$$

Where M and P are as previously defined, and $100P_1'$ the percentage of sole crop population to use.

This is, of course, but a crude guideline and needs more precise data. However, it does seem logical that the higher the ear is in relation to the sorghum canopy, and the longer that situation prevails, then the more light is available for grain yield per plant, and the higher the population should be to optimise yield per unit area.

1. 4. To follow up work at Samaru with cereal mixtures, a series of mixed cereal variety trials were initiated at State locations, as well as Samaru, Kano and Mokwa. The State locations were: Panda, Shinkafi, Yelwa, Bida, Kachia, Saben Gida, Karinsoli, Ladanawa, Yandev, Bokkos, Pankshin, Isanlu-Morkutu, Omu-Aran, and Alapa.

Each trial consisted of six sets of four replications of six plots in 1976.

1. 6 varieties of maize grown sole and mixed with a standard sorghum variety.
2. 6 varieties of maize grown sole and mixed with a standard millet variety.
3. 6 varieties of millet grown sole and mixed with a standard maize variety.
4. 6 varieties of millet grown sole and mixed with a standard sorghum variety.
5. 6 varieties of sorghum grown sole and mixed with a standard maize variety.
6. 6 varieties of sorghum grown sole and mixed with a standard millet variety.

Each trial was fertilised with compound 20:10:10 @ 300 kg. ha^{-1}, except Bokkos and Panshin, which were given compound 12:12:17:2 at the same rate.

Results have been tabulated for Samaru and Kano and are given below. Also are tabulated "A" = Aggressiveness and "R" = Reciprocity.

$$"A" = \left(\frac{Y_{ij}}{Y_{ii}} - \frac{Y_{ji}}{Y_{jj}}\right)/2$$

$$"R" = \left(\left(\frac{Y_{ij}}{Y_{ii}} + \frac{Y_{ji}}{Y_{jj}}\right)/2\right) - 1.$$

If "R" is positive, the mixture has made an overall gain in yield compared with sole crops.

If "A" is positive then any gain in the mixture is because the standard crop yields proportionally better when mixed than the particular variety being tested.

A good mixture would be one where "R" is positive and "A" is either zero, or indicates that the crop of highest value contributes most to the gain.

Samaru

Shelling percentages and dry grain weight have not yet been determined. Data is based on fresh wt. using .60 as a conversion factor to dry grain.

Maize and sorghum..... Table A.14.

Variety	Sole	Mixed	Sorghum mixed	"A"	"R"
B. Local	4942	4615	2260	-.0553	-1.2429
S. 123	5317	5496	2153	-.1247	- .0910
TZA/1	4518	5070	1507	-.2868	- .1642
TZA/2	4175	4632	2512	-.0972	.0123
TZA/3	3637	4452	2117	-.2264	- .0023
096	4827	4501	2117	-.0806	- .1482
EK 5912	2745				

Maize and Millet

Table A 15

Variety	Sole	Mixed	Mixed millet	"A"	"R"
B. Local	3148	3686	2079	-.0230	.1480
S. 123	4795	4436	1862	.0412	-.0336
TZA/1	4045	4175	1740	-.0453	-.0132
TZA/2	3213	3458	1740	-.0673	.0089
TZA/3	3441	3246	1794	.0137	-.0429
096	4257	4143	1903	.0283	.0015
EX Borno(IAR)	1848				

Millet and Maize

Table A 16

Variety	Sole	Mixed	Mixed maize	"A"	"R"
Ex Ghana	2202	2052	4061	.2219	.1538
Ex Benue	2922	3275	4387	.1827	.3035
Nig. Comp.	2528	1346	4176	.4411	-.0265
Ex Borno (K)	1169	1237	4289	.1974	.2555
World Comp.	1767	1400	5154	.4768	.2691
Ex Borno(IAR)	1944	1835	4762	.3346	.2785
096 Maize	2952				

Millet and Sorghum

Table A 17

Variety	Sole	Mixed	Mixed Sorghum	"A"	"R"
Ex Ghana	2936	3278	2583	-.0617	.0548
Ex Bornu	2260	2906	2153	-.2290	.0568
Nig. Comp.	2185	2658	1686	-.2841	-.0677
Ex Borno(K)	2022	2397	2009	-.2065	-.0211
World Comp.	2022	2561	1543	-.3367	-.0701
EX Borno (IAR)	2544	2756	2476	-.0657	.0176
SK.	2601				

Sorghum and Maize

Table A 18

Variety	Sole	Mixed	Mixed Maize	"A"	"R"
181	1543	1148	4974	.3073	.0513
187	2835	2189	7763	.6742	.4463
FFBL	1579	1328	6083	.4103	.2513
1499	2619	2117	6817	.5269	.3352
1412	2835	1615	5643	.4859	.0555
SK 5912	3265	2476	6197	.4672	.2255
096	3661				

Sorghum and Millet

Table A 19

Variety	Sole	Mixed	Mixed millet	"A"	"R"
181	1328	1328	3131	.1094	.1094
187	1758	969	3131	.3338	-.1150
FFBL	1256	2153	2577	.3555	.3506
1499	2547	2691	2887	.0336	.0902
1412	2225	1902	3246	.2043	.0592
SK 5912	2799	1830	3164	.2889	-.0573
Ex B.	2569				

1.--Maize and Sorghum

Maize varieties were: Bemo Local, S. 123, TZA-1, TZA-2 TZA-3 and 096; all mixed with sorghum variety Y.G. Mean Yields are given in Table A20.

Table A20

Yield in kg. grain ha.$^{-1}$

Variety	Sole	Mixed	Sorghum(mixed)	"A"	"R"
B. local	521	1077	394	-.6562	.4110
S. 123	441	1006	552	-.6119	.6593
TZA-1	1374	1020	483	.0915	-.1662
TZA-2	1369	1378	373	-.1388	-.1467
TZA-3	1052	1567	429	-.3339	.1557
096	257	1118	588	-1.6119	1.7383
Y.G.	522			± 1.3258	± 1.4662

+R = gain.

-A = Test crop more aggressive and gives gain.

Sorghum and Maize. Table A.21.

Variety	Sole	Mixed	Maize (mixed)	"A"	"R"
RZ 1	477	217	386	.1849	-.3601
A 9025	251	623	220	-1.0060	.4761
Kano Line A	577	636	1206	.7373	.8396
Kano Line B	44	130	243	1.2177	.7369
Y.G.	419	617	562	-.1358	.3367
096	468				

Sorghum and millet

Table A.22

Variety	Sole	Mixed	Millet(mixed)	"A"	"R"
RZ 1	8	16	2100	-.0028	.9972
A 9025	268	112	1695	.5959	.0138
Kano Line A	30	32	1720	.2834	.3500
Kano Line B	86	17	1599	.6604	-.1419
Y.G.	51	26	1444	.4308	-.0594
Ex. Borno (IAR)	1053				

Millet and Sorghum

Table A.23

Variety	Sole	Mixed	Sorghum(mixed)	"A"	"R"
Ex Ghana	1067	1514	120	-.5054	-.0865
Ex Benue	1353	1589	158	-.3185	-.1441
Nig. Comp.	1032	2320	127	-.9080	.3400
Ex. Borno(K)	1248	1629	20	-.6186	-.3133
World Comp	895	1497	97	-.6713	.0013
Ex Borno (IAR)	1521	1655	123	-.3349	-.2468
Y.G.	294				

Maize and Millet

The same maize varieties with Ex Borno (I.A.R.) as standard millet.

Table 4.24

Yields in kg. grain ha.$^{-1}$

Variety	Sole	Mixed	Millet(Mixed)	"A"	"R"
B. Local	222	133	1936	.4223	.0214
S 121	401	228	1881	.4171	-.0144
TZA-1	969	212	1834	.5744	-.2068
TZA-2	1076	492	1731	.4168	-.1260
TZA-3	502	301	2014	.4511	.0507
095	654	179	2171	.6726	-.0537
Ex Borno	1341				

Millet and Maize

Millet varieties were Ex Ghana, Ex Benue, Nigerian Composite, Ex Borno (Kano), World Composite and Ex Borno(I.A.R); all grown with 096 maize as standard.

Table 4.25

Variety	Sole	Mixed	Maize (mixed)	"A"	"R"
Ex Ghana	1240	1309	81	-.3976	-.3420
Ex Benue	1580	1377	310	.0626	-.0658
Nig. Comp.	1592	1570	228	-.1265	-.1404
Ex Borno(K)	1669	1856	86	-.4178	-.3057
World Comp.	1335	1781	76	-.5449	-.2100
Ex Borno (IAR)	976	1829	734	.2431	1.1171
096	311				

Unfortunately sorghum failed at Kano, and maize yields were poor, millet yielded moderately well. Without analysis of all the data it is premature to draw conclusion. On average, mixed maize produced 42% more grain than sole maize - when grown with a failed sorghum crop, a result to be expected and of little value. When grown with millet, maize yielded very poorly, some 40% of sole crop yield. Millet showed gains when grown with either sorghum (43%) or maize (16%).

At Samaru, where yields were fair for all crops, maize did not lose yield when grown with either sorghum or millet, but showed only small gain. Sorghum consistently lost yield with maize and only two varieties (FFBL, 1499) showed gain when grown with millet. Similarly, millet lost yield overall when grown with maize, and showed gain up to 30% when grown with sorghum.

It is hoped that when data from the entire series of experiment becomes available, and despite high variability because of small plot sizes, real difference will be found between different varieties in their response to mixing, and that these differences can be related to differences in habit.

There were three other trials at Samaru concerning mixed cereals. The trial investigating 3-cereal mixtures cannot be reported since the logbook is, as yet, incomplete.

1.5 Effects of time of application of nitrogen to a mixture of millet and sorghum.

Earlier work had shown that in, as mixture of millet and sorghum, millet removed all its required nitrogen within the first six weeks and this may be to the detriment of sorghum. This experiment was designed to determine if there is a need to split applications to millet and sorghum, so that both would gain much benefit.

There were five fertiliser treatments; 80 kg. N ha^{-1}, as nitrochalk, was either not applied, or applied at sowing, 2 weeks, 4 weeks and 6 weeks after sowing, to each crop grown sole and mixed. A basal dressing of single superphosphate was given the entire experiment before sowing. Ex Bornu millet was grown with sorghum SK 5912. Yields are given in table. A.26

Table A 26. Yield of millet and sorghum in kg. grain ha^{-1} @ 14% m.c.

Time of application	Sorghum		Millet		"A"	"R"
	Sole	Mixed	Sole	Mixed		
-	1441	1617	1234	1294	.0368	.0854
0	3337	2901	2587	2341	-.0178	-.1129
2	2141	2079	1783	1760	-.0080	-.0209
4	3657	3517	1910	1712	.0327	-.0710
6	3518	3311	1928	1654	.0416	-.1005
LSD. I	527	356	336	225		

Only when nitrogen was applied at sowing was there a differential response to nitrogen by sorghum grown sole or in the mixture. When applied at sowing, sorghum responded considerably better as a sole crop.

Apart from the apparently anomalous yield of sorghum when N was applied 2 weeks after sowing, there was no difference in response to time of application by sole sorghum. Mixed sorghum, however, responded best when nitrogen was applied late. Millet, whether sole or mixed, always responded best when N was applied at sowing.

1.6. The final experiment with cereal mixtures was with three varieties of sorghum and three varieties of millet in all pairs of combination.

FFBL, SK 5912 and SE 187 sorghum were each grown with Ex-Ghana, Ex-Borno and Nigerian Composite millet. Sole crops were not grown. Yields are given in Table A.27

Table A 27

Yield in kg. grain ha^{-1} at 14% m.c.; height at maturity

Mixture	Sorghum	Millet	Plant Height	
			Sorghum	Millet
FFBL / Ex. G.	2372	1088	320	210
Ex. B.	2341	1198	360	220
N. C.	2219	1604	352	245
SK 5912/ Ex. G.	2131	1300	165	229
Ex. B.	2267	1495	175	217
N.C.	2049	1218	200	235
SE 187/ Ex. G.	1960	1196	183	230
Ex. B.	2189	1310	165	205
N.C.	1971	1241	177	245

There was little difference between yields of sorghum when with different millet varieties. Millet, however, did consistently better when grown with shorter, slower growing sorghum (SK 5912, SE 187). When grown with FFBL, whose canopy height kept pace with millet until millet matured, millet showed reduction in yield.

In summary, where mixtures of cereals are concerned, consistent gains from mixing have been difficult to show. However, real losses have been very rare and there appears no justification to advise farmers to grow sole crops on this ground.

When these mixtures are examined closely there is a definite association between difference of canopy structure and yield gain, whether the difference of canopy structure is induced by harvest dates (or sowing dates) or height.

There is no doubt that correct selection of varieties for mixtures will lead to gain, and that these gains can be increased by timely fertiliser application and modifying plant population.

1.2. <u>Mixtures involving groundnuts</u>

In addition to the trials at Samaru over the past three years, trials with groundnuts grown "gioi" with cereals were initiated

at the following locations in 1976: Gwanzo, Malam-Madiri, Gusau, Talata Mafara, Kaura Namoda, Bida, Maigana, Saminaka, Sabon Birnin Gwari, Daura, Kafinsoli, Butsari, Oturkpo, Mbatu, Keffi, Wawa and Okuta.

Samaru

There were seventeen treatments, listed below in four groups, arranged in four replicates of a randomised blocks design in each of the three years, 1974-1976.

1. Sole crop groundnuts sown 0.23m apart on ridges .91m apart; two other treatments did not have groundnuts sown at intervals of 1.37m or 2.74m to serve as controls for comparison with intercropped groundnuts.

2. Millet or sorghum or maize sown in place of groundnut at intervals of 1.37m or 2.74m along the ridge.

3. All combinations of pairs of maize, millet and sorghum sown alternately along the ridge at intervals as above.

4. Maize, millet and sorghum sown in sequence along the ridge at intervals as above.

Varieties were: maize, Samaru composite 123, harvested after 110 days; millet, landrace ex-Ghana, harvested after 75 days; sorghum variety Short Kaura 5912, harvested after 160 days; and S 38 groundnut harvested at the end of the rains in each year (113, 130 and 140 days in 1974, 1975 and 1976 respectively).

The experiments were sown on 13th June 1974, 26th May 1975 and 31st May 1976.

Gross plot was 8 ridges each 13.72m along (0.01 ha.), and nett plot for harvest consisted of 10.97m from each of the centre 6 ridges (0.006 ha.), although threshing percentage of groundnuts was determined from the centre 2 ridges only.

Each experiment received a basal dressing of 54 kg./ha^{-1} P_2O_5 ha^{-1} applied at sowing, and 0.5 kg. B ha.$^{-1}$ applied as solubor in 1974, and in boronated superphosphate in the other years. Each experiment was sprayed with benlate fungicide at regular intervals from flowering of groundnuts to control Cercospora leafspots of groundnuts.

Yields for each crop were analysed separately for each year and in combined analyses over all years, and are given in the following Tables.

Table 4.28

Yield of groundnuts as unshelled nuts in kg. ha.$^{-1}$

Treatment	1974	1975	1976	Mean
Sole groundnut	3219	837	3466	2507
With gap at 1.37m	3138	797	3002	2312
" " " 2.74m	3381	976	3157	2505
Mean sole groundnut	3246	870	3208	2441
With maize at 1.37m	2228	704	2939	1957
" " " 2.74m	2629	904	3293	2275
With millet at 1.37m	2447	708	3621	2259
" " " 2.74m	2323	673	3130	2042
With sorghum at 1.37m	2609	668	1811	1696
" " " 2.74m	2515	767	2302	1861
With maize/millet at 1.37m	2254	667	3048	1989
" " " " 2.74m	2974	737	2829	2180
With maize/sorghum at 1.37m	1954	638	2256	1616
" " " " 2.74m	2695	803	2675	2057
With millet/sorghum at 1.37m	2257	603	2693	1851
" " " " 2.74m	2961	733	3030	2241
With maize/millet/sorghum at 1.37m	2175	701	2866	1914
With maize/millet/sorghum at 2.74m	2316	862	2693	1957
Mean mixed groundnut	2452	726	2799	1992
Mean	2592	751	2871	2071
S.e. single plot ±	406.3	153.3	453.7	362.6

Table A.29

Yield of maize as kg. grain ha.$^{-1}$ at 14% m.c.; yield per plant in kg. grain at 14% m.c.

Treatment	1974		1975		1976		Mean	
At 1.37m	2346	.292	840	.104	278	.035	1155	.144
" 2.74m	1332	.332	400	.100	133	.033	622	.144
+ millet at 1.37m	1032	.257	281	.070	101	.025	421	.117
" " " 2.74m	703	.350	200	.098	30	.014	311	.155
+ sorghum at 1.37m	887	.222	431	.107	223	.056	514	.128
" " " 2.74m	365	.182	152	.076	72	.036	196	.098
+ millet/sorghum at 1.37m	735	.275	185	.069	130	.048	350	.131
" " " " 2.74m	416	.311	155	.116	42	.031	204	.153
S.e. single plot ±	250.3	.085	207.1	.040	177.0	.041	213.6	.053

Table A.30

Yield of sorghum as kg. grain ha.$^{-1}$ at 14% m.c.; yield per plant in kg. grain at 14% m.c.

Treatment	1974		1975		1976		Mean	
At 1.37m	1245	.155	1391	.173	2221	.277	1619	.202
" 2.74m	729	.182	766	.191	1169	.292	888	.222
+ maize at 1.37m	615	.154	756	.188	1371	.342	914	.228
" " " 2.74m	153	.076	446	.222	494	.246	364	.182
+ millet at 1.37m	671	.167	710	.177	1008	.252	796	.198
" " " 2.74m	322	.161	310	.155	389	.194	340	.170
+ maize/millet at 1.37m	264	.099	484	.181	798	.293	515	.191
" " " " 2.74m	121	.090	224	.167	295	.221	213	.160
S.e. single plot ±	228.8	.058	93.3	.032	364.3	.076	265.1	.049

Table A 31

Yield of millet in kg. grain ha.$^{-1}$ at 14% m.c.; yield per plant in kg. grain at 14% m.c.

Treatment	1974		1975		1976	
At 1.37m	2486	.310	182	.023	958	.120
" 2.74m	1150	.287	116	.029	664	.166
+ maize at 1.37m	1840	.459	85	.021	698	.174
" " " 2.74m	722	.360	63	.031	300	.150
+ sorghum at 1.37m	1212	.302	96	.024	456	.114
" " " 2.74m	658	.328	71	.035	302	.151
+ maize/sorghum at 1.37	1939	.726	58	.022	516	.193
" " " " 2.74m	795	.595	38	.028	344	.257
S.e. single plot	584.7	.200	21.5	.007	147.0	.048

Table A.32

Mean millet yield for the period 1974-1976 as kg. grain ha.$^{-1}$ at 14% m.c. mean $\log_{10}$ kg. grain ha.$^{-1}$ at 14% m.c.; yield per plant at 14% m.c.; mean $\log_{10}$ yield per plant at 14% m.c.

Treatment	kg.ha^{-1}	Mean log kg. ha.$^{-1}$	10kg./pl	Mean log kg./pl. $_{10}$
At 1.37m	1209	2.8731	.151	$\bar{1}$.0304
" 2.74m	543	2.6144	.160	$\bar{0}$.9899
+ maize at 1.37m	874	2.6297	.218	$\bar{0}$.9740
" " " 2.74m	362	2.3146	.180	$\bar{0}$.9886
+ sorghum at 1.37m	588	2.5364	.147	$\bar{1}$.0668
" " " 2.74m	343	2.3138	.171	$\bar{0}$.9894
+ maize/sorghum at 1.37m	838	2.5926	.314	$\bar{0}$.8436
" " " " 2.74m	392	2.3078	.293	$\bar{0}$.8198
S.e. single plot	-	0.2017	-	0.2024

Table A 33

Mean yield of groundnuts as unshelled nut in kg. ha.$^{-1}$

Treatment	1974		1975		1976		Mean	
	kg.	±	kg.	±	kg.	±	kg.	±
Sole groundnut	3246	117.3	870	44.3	3208	131.0	2441	60.4
Mixed "	2452	54.3	751	20.3	2871	60.8	1992	28.0
With 1 cereal	2458	82.9	737	31.3	2849	92.6	2015	42.7
" 2 cereals	2516	82.9	697	31.3	2730	92.6	1981	42.7
" 3 cereals	2245	143.6	782	54.2	2780	160.4	1936	74.0
Cereals at 1.37m	2275	76.8	670	29.0	2748	85.7	1898	39.6
Cereals at 2.74m	2630	76.8	750	29.0	2850	85.7	2077	39.6

Table A 34

Gross cash return in naira (₦) for sole and intercropped groundnuts

Treatment	1974	1975	1976	Mean
Sole groundnut	338	147	607	364
With gap at 1.37m	329	139	526	331
With gap at 2.74m	355	171	552	359
Mean sole groundnut	341	152	562	352
With maize at 1.37m	471	209	570	416
" " " 2.74m	410	198	603	404
With millet at 1.37m	649	153	808	536
" " " 2.74m	425	129	668	407
With sorghum at 1.37m	445	273	823	503
" " " 2.74m	345	220	669	411
With maize/millet at 1.37m	632	159	680	490
" " " " 2.74m	514	159	555	409
With maize/sorghum at 1.37m	365	240	751	452
" " " at 2.74m	337	206	577	373
With millet/sorghum at 1.37m	503	200	784	496
" " " " 2.74m	451	174	673	433
With maize/millet/sorghum at 1.37m	639	205	781	541
" " " " " 2.74m	424	199	609	411
Mean mixed groundnut	470	195	682	449
Mean	447	187	661	
S.e. single plot ±	85.4	29.0	98.6	77.2

(Cash value of crop in ₦ 100 kg.$^{-1}$

Maize	10.20	10.20	19.80
Millet	15.78	15.78	18.15
Sorghum	11.19	11.19	22.77
Groundnut	10.50	17.50	17.50*)

* 0.70 of Marketing Board for shelled nuts.

Groundnut yields were good except in 1975 when they were under severe moisture stress during a 20 day period at flowering in June. Potential evapotranspiration exceeded rainfall by 55.5mm in this period. They were further adversely affected by another drought period, for 25 days during early pod filling in August. Potential evapotranspiration exceeded rainfall by 31.0mm at that time. Similarly millet yields were badly affected by the early drought period, whilst maize yields were also affected by the later drought. Short kaura sorghum which, after early vegetative growth, shows very little growth until flowering at the end of September, was not affected by either drought period.

For all joint analyses, Bartlett's test for heterogeneity of variance was done and gave corrected X^2 for groundnuts, 2.0706; maize yield ha.$^{-1}$, 0.2384; maize yield per plant, 1.5675; sorghum yield ha.$^{-1}$, 2.7292; and sorghum yield per plant, 1.2374. None were significant. However, Bartlett's test for the joint analysis of millet data gave X^2 of 11.4310 for yield ha.$^{-1}$, and 10.4676 for yield per plant. Both were significant and a $\log_{10}$ transformation was used for this analysis, given separately in Table 4.32 . The transformation reduced X^2 to 2.1181 and 2.0967 for yield ha.$^{-1}$ and per plant respectively. Neither were significant.

Groundnuts

Sowing groundnuts with gaps at 1.37m and 2.74m did not affect yield of groundnuts in any year, nor overall. However, sowing cereals within these gaps significantly reduced yield in each year and overall. Mean yields for sole and mixed groundnuts are given in Table 1. Only in 1976 was there any difference between cereals in their effect on groundnut yield. In that year sorghum significantly reduced groundnut yield more than maize or millet. Although this effect was not detected in any other year it is an effect to be expected since sorghum is harvested 160 days after sowing, and is thus competing with groundnut for the full period from sowing to lifting of ground (113 days in 1974, 130 days in 1975, and 140 days in 1976). The other cereals, maize and millet, were harvested 110 and 75 days after sowing respectively in each year. As a generality, however, no cereal affected groundnut more than another.

Sowing cereals within groundnuts 1.37m apart significantly reduced groundnut yield compared with sowing 2.74m apart. Mean

yields for groundnut with cereals at different spacing, and for different cereals, are given in Table A.34

Cereals.

Although spacing, and the proportion of any one cereal in the mixture, significantly affected cereal yield ha.$^{-1}$ examination of yield per plant showed that no treatment had any effect. Plant population ha.$^{-1}$ (8020 at 1.37m, and 4010 at 2.74m) was sufficiently low to prevent competition between cereals.

Gross cash return ha.$^{-1}$

Total cash value of yield in naira (₦) based upon Marketing Board purchasing price for groundnuts in November each year, and local market prices for cereals during the month of harvest, are given in Table ....

Bartlett's test for the joint analysis gave a X^2 of 2.3072, which was not significant.

Mixed cropping significantly increased cash return in each year, and averaged 27.7% cash gain overall years. Despite poor yields of one crop or another in each year, the buffering action of the yield of other crops was sufficient to always give greater returns from mixtures.

Sowing cereals at close spacing (1.37m) within groundnuts significantly increased cash return compared with sowing at wide spacing. Cash return from close spaced mixtures was ₦490.7 ±8.4, and from wide spacing was ₦407.0 ± 8.4. There was no difference between cash returns from mixtures with different cereals, nor between mixtures with one or two cereals. The mixture with all three cereals was significantly better than single and double cereal mixtures at 0.068 probability, giving ₦476.0 ± 15.7 compared with ₦444.1 ± 6.4.

Thus, although there was no evidence that mixtures gave less variable returns than sole groundnuts (coefficients of variation for mixtures was 51.2%, for sole groundnuts was 51.5%), the consistently, and significantly, greater cash returns obtained from mixtures confirmed that are correct to reject recommendations to grow sole groundnuts. Although sole crop cereals were not grown in these experiments, extrapolation from good average yields, and adding the value to sole crop groundnuts, did not give cash returns comparable with mixtures.

These experiments have demonstrated that "gicci" intercropping is more profitable than sole cropping, and have also shown possible improvements to the system by (a) sowing cereals at a higher density than normally sown by farmers - 3 to 4 m and (b) by including the third crop maize in the mixture. Further improvements can be made by adding nitrogenous fertiliser, particularly to maize, and, possibly, by harvesting and selling maize as green ears to a very early market.

States location results are not reported here in full because data has not yet been extracted from the log books. However, logbooks from Gusau and Kafinsoli suggest that sole groundnuts gave higher cash return than mixed groundnuts. Inspection reveals that this reversal of the results from Samaru was due to very poor cereal yields, almost certainly because no nitrogen was applied to cereals.

In future trials, two further components must be added, fertilising the cereals separately and, particularly, varying the sowing date of the cereal to be more in keeping with farmers practice. In one trial at Samaru, not reported here, where cereals were sown with the first rain and at the normal time, it was clear that cereals sown very early benefitted greatly from the early nitrogen "flush" at the beginning of the rain. Later sown, unfertilised cereal, was very poor. Further, groundnuts also benefited from the reduced overlap from earlier sown maize being harvested earlier.

Cereals/cowpea

An experiment to determine the effects of intercropping different varieties of cowpea with cereals on yield of cowpea was begun at IAR in 1976 as part of a co-operative trial with I.I.T.A.

Eight varieties of cowpea were sown under established crops of three maize varieties (Upper Volta early, Samaru 123 and 096). Maize was all sown on 1 June 1976 and cowpeas were undersown six weeks later, on 12 July 1976.

Upper Volta early maize was harvested on 30 August 1976, some eight days before cowpea began flowering. Samaru 123 and 096 were harvested on 20 September and 29 September respectively. Cowpea varieties reacted 50% flowering between 19th September and 10th October and were thus completely unprotected by maize during pod formation and maturation.

Maize yields were unaffected by the presence of cowpea but cowpea yields were affected by length of overlap with maize. Yields, as dried pods and maize grain at 11% m.c. in kg. ha^{-1} are given in Table A.35

Table A 35

Cowpea	% Stand	kg. d.p. ha.$^{-1}$	7.7 50% ft.	Maize	kg. g. 14% m.c. ha^{-1}	Sole maize
7	49	915	7.10	Upper V. early	4323	4308
3	64	374	27.9	"	4323	
589/2	65	442	2.1(	"	4446	
2479	59	1381	7.1(	"	4214	
593	56	515	28.9	"	4308	
556/2	55	937	19.9	"	4054	
1696	62	1859	8.1(	"	4359	
TVU 4557	63	514	18.9	"	4294	
7	45	134	11.10	Sam. 123	6876	6310
3	61	111	5.10	"	6491	
588/2	74	468	10.10	"	6521	
2479	68	538	3.10	"	6868	
593	64	551	4.10	"	6778	
556/2	64	305	8.10	"	6762	
1696	54	752	8.10	"	6423	
TVU 4557	66	267	4.10	"	6812	
7	57	141	10.10	096	5706	6328
3	53	143	3.10	"	6488	
588/2	54	391	1.10	"	5776	
2479	59	400	5.10	"	5650	
593	48	302	8.10	"	5343	
556/2	72	255	8.10	"	5824	
1696	48	430	5.10	"	6430	
TVU 4557	56	148	25.9	"	6352	
S.e. mean						

It is important to stress that no protection was given against insects; cowpeas were not sprayed. It is also regretted that sole cowpeas were not sown. Nevertheless, the yields of cowpea varieties 2479 and 1696 when grown under Upper Volta early maize are quite exceptional for unsprayed cowpea. Reasons why these varieties were not attacked by insects are not known.

1.4. Cotton/Cowpea/Cereals

Cotton and cowpea are normally sown late in the year, generally, July or August. This is despite current recommendations for June sowing. Farmers are not prepared to leave land unused until this time and it is not possible to sow cotton after cereal, unless the cereal is harvested before maturity, or unless the cotton is sown much later than optimal. This latter is often normal practice amongst farmers, and, because lower yields are obtained, spray regimes are uneconomic. This experiment was designed to determine whether cotton could be sown earlier, within the cereal, so as to obtain the benefit accruing from early sowing, and whether spraying with insecticide would then be economic. Further, since farmers often grow cotton and cowpea mixed, both cowpea alone and mixed with cotton were included as relay treatments.

There were three main treatments: either millet or maize as the early cereal, or no cereal sown at all. Each of these included the following four treatments:

a) Cotton alone sown within the cereals, or, where no cereal had been sown, grown sole as a normal crop.

b) Cowpea alone sown within cereals, or, where no cereal had been sown, grown sole.

c) Cotton and cowpea grown in a 2:1 ratio within the cereal; i.e. cotton under-sown on two ridges, cowpea undersown on one ridge. The same mixture being also sown without being preceded by a cereal.

d) Cotton and cowpea grown in a 1:2 ratio within the cereal; i.e. cotton under-sown on one ridge, cowpea undersown on two ridges. Similarly where no cereal was present.

There were two blocks of these 12 treatments (3 early x 4 relay), one was protected against insects by U.L.V. spraying with endosulfan, the other not sprayed. Where cotton or cowpea were not mixed each was sprayed six times; with cotton and cowpea mixed they were sprayed four times.

Both millet, var. ex-Borno in 1974, and 1975 and maize, var. B.S. 3, were sown 23 cm. (9") apart along 91 cm. (3') ridges, and both were fertilised at sowing with 627 kg. ha.$^{-1}$ (5 cwt./acre) with the compound fertiliser 20:10:10:N:P:K. Both were sown on 7th June, 1974.

Table A36

Cereal	Treatment Cott.	Treatment Cowp.	Cereal 1974	Cereal 1975	Cereal 1976	Cereal Mean	Sprayed Cotton 1974	Sprayed Cotton 1975	Sprayed Cotton 1976	Sprayed Cotton Mean	Sprayed Cowpea 1974	Sprayed Cowpea 1975	Sprayed Cowpea 1976	Sprayed Cowpea Mean	Unsprayed Cotton 1974	Unsprayed Cotton 1975	Unsprayed Cotton 1976	Unsprayed Cotton Mean	Unsprayed Cowpea 1974	Unsprayed Cowpea 1975	Unsprayed Cowpea 1976	Unsprayed Cowpea Mean
Millet	-	-	2828	2172	2378	2459	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	3316	2712	2433	2820	231	317	815	454	-	-	-	-	301	177	676	-	-	-	-	-
	2	1	2885	2382	2574	2594	227	178	292	232	480	661	612	584	197	74	101	-	198	285	96	193
	1	2	3086	2512	2415	2671	65	91	118	91	746	962	835	848	95	29	25	-	234	196	96	175
	-	3	3158	2741	2473	2791	-	-	-	-	788	1097	1136	1007	-	-	-	-	369	5	8	127
Maize	-	-	5827	4693	4253	4924	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	5727	4664	4412	4934	230	300	851	460	-	-	-	-	345	237	919	486	-	-	-	-
	2	1	5569	4592	4349	4837	122	245	334	234	207	810	1152	723	290	89	87	155	233	276	49	186
	1	2	5727	4521	4289	4846	78	82	116	92	622	965	1093	893	93	35	84	71	320	263	11	198
	-	3	5641	4707	4411	4920	-	-	-	-	613	1213	1356	1061	-	-	-	-	345	36	17	133
None	3	-	-	-	-	-	1161	1414	1047	1207	-	-	-	-	941	729	968	879	-	-	-	-
	2	1	-	-	-	-	703	531	436	557	713	1082	1092	962	465	233	143	280	46	28	11	28
	1	2	-	-	-	-	281	142	64	162	1123	1231	1217	1190	182	99	53	111	37	7	9	18
	-	3	-	-	-	-	-	-	-	-	1189	1358	1373	1307	-	-	-	-	2	3	3	3

Cotton, Samaru 71, was sown on 18th July, at 45 cm. spacing either alone or beneath the cereals on the same ridge. Cotton was fertilised with 188 kg. ha.$^{-1}$ (156 lb./acre) boronated Rustica compound fertiliser (12:12:17:2::N:P:K:Mg plus 0.6% B) when the cotton was sown.

Cowpea, local Farinwake, was sown at 90 cm. spacing along the ridge either alone or beneath the cereals on the same ridge. Cowpea was not given additional fertiliser.

Cereals were sown later than normal as a result of poor early rains. Thus the overlap between sowing of cotton/cowpea and harvesting of each cereal was longer than might normally be expected. These were 40 days for millet, harvested on 5th September, and 70 days for maize, harvested on 26th September.

Yields from these crops and mixtures are given in Table 20 and the nett value per hectare, after deducting fertiliser and spraying costs (but not labour), are given in table 21.

Yield of cereals was totally unaffected by the later sown crop. Yield of cotton was greatly affected by relaying and showed no compensation for a reduced population in a mixture. Cowpea, although affected by cereals, showed considerable compensation when grown as a component in a mixture. Further, and of great interest, unsprayed cowpea when sown relay gave very much higher yields than unsprayed cowpea sown alone. Observations suggest that the vigour of under-sown cowpea was so much reduced by early shading from the cereal that cowpea plants were less attractive to the pest Maruca. This pest caused almost complete flower bud shedding in unsprayed cowpea sown alone.

Table A 37 gives nett cash returns per hectare pricing cotton at ₦19.84, cowpea at ₦21.65, maize at ₦10.20 and millet at ₦15.78 per 100 kg. bag for 1974.

Spraying was costed at ₦7.05 per applications; ₦42.32 for the six sprays given cotton or cowpea sown alone, with or without cereal. All fertiliser was costed at a rate of ₦200/tonne.

When deducting spray cost for cotton and cowpea in a mixture the appropriate proportion was deducted from each. E.g. $\frac{2}{3}$ of the cost of spraying was deducted from the value of cotton in a 2:1 mixture, $\frac{1}{3}$ of the cost from cowpea.

Table A 37

Nett value of crops and total returns/ha.$^{-1}$

Treatment				Sprayed			Unsprayed		
Cer.	Cott.	Cowp.		Cott.	Cowp.	Total	Cott.	Cowp.	Total
			₦	₦	₦	₦	₦	₦	₦
Mi	-	-	418.33	-	-	418.33	-	-	418.33
"	3	-	418.33	- 19.44	-	393.89	22.26	-	440.99
"	2	1	418.33	1.56	94.53	514.42	14.37	42.87	475.47
"	1	2	418.33	- 8.85	142.72	522.20	6.49	50.66	475.48
"	-	3	418.33	-	128.29	546.62	-	79.89	498.22
Ma	-	-	517.45	-	-	517.45	-	-	517.45
"	3	-	517.45	- 19.62	-	497.83	31.38	-	548.83
"	2	1	517.45	- 28.09	35.18	524.18	32.85	50.44	600.74
"	1	2	517.45	6.26	155.88	627.07	6.10	69.28	592.83
"	-	3	517.45	-	90.40	607.85	-	74.69	592.14
None	3	-	-	150.97	-	150.97	149.63	-	149.63
"	2	1	-	96.09	140.27	236.27	67.57	9.96	77.53
"	1	2	-	34.09	217.11	251.12	23.77	8.01	31.78
"	-	3	-	-	215.11	215.11	-	0.43	0.43

(1974 and 1975 only)

Conclusions:

1. Neither cotton nor cowpea, sole or mixed, sprayed or unsprayed, gave nett returns which compensated for the absence of an early cereal.

2. Because yield of cereals, which contributed the largest amount of nett value, was not affected by relay cropping, all mixtures gave greater nett returns than cereals alone except when sprayed cotton was the only other constituent of the mixture. Yield of cotton was so affected by relaying that spray costs were not recovered and sprayed cotton lost money.

3. In all cases, whether sprayed or unsprayed, cowpea gave good nett cash returns except when grown unsprayed without a preceding cereal. This crop failed.

Thus: Even in a season where the late start meant a longer than normal overlap between cereals and the relay crop, a system of cereals relayed with cowpea proved very rewarding, particularly so if maize were the preceding cereal.

1.5. Cotton and Cereals

Two experiments were done, in 1975 and 1976, with cotton var. Samaru 71, sown at four dates, both sole and through four cereals. The cereals were: landrace ex Ghana millet (75 days to maturity), landrace ex Borno millet (85 days to maturity), Bomo local maize (90 days to maturity), and R 960 sorghum (106 days to maturity).

There were four sowing dates for cotton in each year, at 21 day intervals from the first. All cereals were sown at the first date, both sole and for subsequent sowing with cotton. Cereals were sown 23cm apart on ridges 71cm. apart; cotton was sown on the side of the ridge between alternate cereal plants in 1975 (46cm. apart). and between cereal plants in 1976 (23cm. apart).

Three replications of a randomised block design was used in each year. Gross plot size was ten ridges (9.14m long in 1975) 7.32m long in 1976). Nett plot for harvest was the centre eight ridges (.0052 ha. in 1975, .0042 ha. in 1976).

The 1975 experiment was given 300 kh $ha.^{-1}$ of compound 20:10:10: N:P:K., whilst 800 kg. ha^{-1} of the same compound was given in 1976. All fertiliser was applied to the seed bed before the first sowing date in each year.

All plots were sprayed with insecticide (Carboryl) at weekly intervals, .68 kg. $ha.^{-1}$ of 85% a.i. in Vetox 85, beginning nine weeks after the first sowing date.

Cereals were harvested when mature, and the entire plant removed from the plots.

Cotton was picked at regular intervals beginning in October and extending to January in each experiment.

Results

Cereals

Bartlett's test for heterogeneity of variance for cereals within each year gave corrected X^2 of 5.5463 and 7.2190 for 1975 and 1976 respectively, neither significant, and a X^2 of less than 0.01 for the joint analysis over both years. Yields of cereals are given in Table A 38.

Table A 38

Cereal yields as grain in kg. $ha.^{-1}$ at 14% m.c.

Treatment	1975	1976	Mean
Ex Ghana millet, sole	1528	2204	1866
With cotton sown at same time	1519	2204	1862
" " " 21 days later	1471	1960	1716
" " " 42 " "	1376	1948	1662
" " " 63 " "	1456	1887	1672
Ex Borno millet, sole	1748	1657	1703
With cotton sown at same time	1593	1354	1474
" " " 21 days later	1665	1477	1571
" " " 42 " "	1489	1452	1471
" " " 63 " "	1602	1539	1571
R 960 sorghum, sole	1277	426	851
With cotton sown at same time	1161	864	1013
" " " 21 days later	1583	535	1059
" " " 42 " "	1548	791	1170
" " " 63 " "	1453	487	970
Bomo local maize, sole	4983	4003	4493
With cotton sown at same time	4278	3409	3844
" " " 21 days later	4574	3988	4281
" " " 42 " "	5397	3745	4571
" " " 63 " "	5247	3761	4504
S.e. single plot ±	505.6	484.8	436.4

Table A 39

Yield of cotton in kg. seed cotton $ha.^{-1}$

Treatment	1975	1976	Mean
Sole cotton sown at D1	1899	3081	2490
" " " " D2	362	2152	1257
" " " " D3	1288	1273	1281
" " " " D4	906	538	722
Sown with ex Ghana millet at D1	1236	1831	1534
" " " " " " D2	464	1028	778
" " " " " D3	569	650	660
" " " " " D4	317	252	317
Sown with ex Borno millet at D1	823	1278	1050
" " " " " D2	684	608	646
" " " " " D3	496	362	429
" " " " " D4	266	144	205
Sown with B. local maize at D1	635	944	789
" " " " D2	549	697	623
" " " " D3	178	143	160
" " " " D4	130	44	87
Sown with R 960 sorghum at D1	523	792	658
" " " " D2	164	511	337
" " " " D3	20	20	60
" " " " D4	4	2	10
S.e. single plot	227.5	300.1	266.3

(Barlett's test for heterogeneity of variance for the joint analysis gave a X^2 of less than 0.03, not significant).

The presence of cotton did not affect cereal yields in any year, nor overall. Yields of cotton, however, were markedly affected by both sowing date and by mixing with cereals. The linear and quadratic components of the total variation associated with the effect of sowing date on yield of cotton mixed with cereals accounted for all that variation, whilst the linear and quadratic components of variation in cotton yield due to different cereals accounted for 98% of the variation. The equation relating cereals and sowing date with cotton yield is given below:

$$\text{Yield} = 6969 - 24.7D - .05D^2 - 115.7C - .21C^2$$

$$D = 1, 22, 43, 64 \text{ days} ; \quad C = 75, 85, 90, 106 \text{ days.}$$

It is important to sow cotton early, whether sole or mixed. If mixed it is equally important to sow cotton with the cereal and with a short season cereal.

When sown mixed with a cereal, cotton responded by a reduction in the number of branches and delayed flowering. When the cereal is removed, flowering and boll production proceeds more rapidly than for sole crop cotton, although maturation was delayed. The bulk of yield from sole crop cotton was produced from early picks, whilst for mixed cotton this came from late picks. Thus there is an additional advantage from mixing very early sown cotton in that maturation and picking is delayed until well after the rains.

Sowing cotton with cereals seems to have considerable promise for areas where cereals are normally sown later in the year, around Gusau for example, or where rainfall permits a double season.

1. 6 Maize, Soybean, Cowpea

The objectives of this experiment were to study (a) the effect of intercropping of maize with soybean and cowpea on the mean grain yields and nitrogen content of the crops, (b) the effect of such cropping system on soil nitrogen and the yield of subsequent crop and (c) the contribution if any, of nitrogen from the legumes to maize intercropped with them.

In 1976, maize was intercropped with soybean or cowpea. Nitrogen was applied to some plots at the rate of 70 kg/ha. Both soybean and maize were sown in early June and the cowpea in mid-July. The varieties used were: -

Maize:	0 96
Soybean:	Malayan
Cowpea:	Aco 588/2.

Data for nitrogen content of the three crops is not yet available, and the residual effects on soil and yield of the subsequent crop will be determined in the next cropping season. The mean grain yield of maize as affected by intercropping with soybean or cowpea at Samaru in 1976 is summarised, in Table A 42

Table A 42. Mean grain yield of Maize in kg/ha

Treatment	Yield (kg.ha.)
Sole maize	2693
Sole maize + nitrogen	3560
Maize + Soybean	2826
Maize + soybean + nitrogen	3332
Maize + Cowpea	1813
Maize + Cowpea + nitrogen	2816
S.E.	.359
L.S.D. (P.= .05)	·717

The analysis showed that intercropping of maize with soybean without nitrogen gave slightly higher yield of maize than the sole crop maize without added nitrogen but incidentally the effect was not significant. Maize with soybean gave a significantly higher yield than maize with cowpea. The greater depression of maize yield by cowpea compared to soybean is surprising, considering that cowpea was planted in mid-July by which time the maize was well established,

while on the other hand soybean was planted at the same time as maize. The reason for this may require a further experimentation.

Addition of nitrogen increased the yield of maize intercropped with soybean to 3332 kg/ha. Also, addition of fertilizer N increased the yield of maize intercropped with cowpea, although the yield was less than that of maize intercropped with soybean plus nitrogen.

Yields of soybean and cowpea: Table A43 shows the yield of soybean and cowpea as affected by intercropping with maize and nitrogen fertilizer.

Table A 43 -

Yield of soybean and cowpea

Treatment	Soybean Yield (kg/ha)	Treatment	Cowpea Yield (kg/ha)
Sole soybean	1956	Sole cowpea	555
Soybean + maize	821	Cowpea + maize	472
Soybean + maize + nitrogen	924	Cowpea + maize + nitrogen	462
S.E.	80	S.E.	91
L.S.D. (P. = .05)	168	L.S.D. (P = .05)	190

Sole crop soybean greatly outyielded soybean intercropped with maize, regardless of added nitrogen. Cowpea yields whether sole or intercropped were very low. The main reason for these low yields could be attributted to shading effect from the maize. Insect damage did not appear to be a major problem even though there was no spraying.

Table A44 - Summaries of total grain yield per unit area

Treatment	Yield (kg/ha)
Sole maize	2693
Sole soybean	1956
Sole cowpea	555
Sole maize + nitrogen	3560
Maize + Soybean	3647
Maize + cowpea	2285
Maize + soybean + nitrogen	4256
Maize + cowpea + nitrogen	3278

The yield per unit area was greatest where maize was intercropped with soybean, especially if nitrogen fertilizer was also added.

From the result of this experiment soybean appeared to be a better companion crop for maize than cowpea, but on the other hand both soybean and cowpea seemed not to have contributed any significant nitrogen to the intercropped maize. For greater yield from the land there is the need to apply nitrogen to maize in a mixture with legume.

1.4. Remaining State trials

In addition to cereal variety intercropping trials, and c cereals groundnut trials done at State locations, experiments were also undertaken with a variety of crop mixtures. These are listed below:

a) Early cereals and cotton at Zuru, Gusau, Mokwa R.J., and Konan Kuka

b) Maize/Sorghum/Yam/Cowpea at Abuja, Minna, Bope, Idah, Lafia, Kabba and Ilorin.

c) Maize/Sorghum/Cowpea at Hong, Mubi, Ngurore

d) Yam/Cowpea/Millet at Mazu Selbe, Sesti

e) Yam/Cowpea/Melon/Maize at Yandev. (d and e also compared local practice of mounds with ridges).

f) Cereals/Groundnut/Cowpea at Katsina Ala and Gagnun,

g) Cassava/Cowpea at Kaura Namoda, Mokwa

h) Sorghum/Late Millet/Melon at Bida.

Not all logbooks have been received and of these received time has allowed the results from, but a few to be given here.

1. 4. 1. Cotton/Cereals

These trials were similar to those at Samaru but simpler; only three sowing dates were used with three cereals. Results are given in Table A.45. and A.46. for Gusau and Konan Kuka.

Table A 45

Yield of Cereals and Cotton - Gusau

Treatment		Cotton	Cereal	Value ₦
Cotton sown	D_1	663		205
	D_2	561		174
	D_3	445		138
Ex Ghana Millet		-	2204	400
Ex Borno Millet		-	2283	414
B. Local Maize		-	1865	369
Ex Ghana with Cotton	D_1	320	1840	433
	D_2	299	1549	373
	D_3	327	1728	415
Ex Borno/Cotton	D_1	303	1736	409
	D_2	331	1970	460
	D_3	274	1940	437
B. Local/Cotton	D_1	345	1941	491
	D_2	277	1425	368
	D_3	258	1095	294

Table A 46

Yield of Cereals and Cotton, Konan Kuka

Treatment		Cotton	Cereal	Value ₦
Cotton sown	D_1	1488	-	461
	D_2	1383	-	479
	D_3	1456	-	451
Ex Ghana			435	79
Ex Bornu			416	76
B. Local			2735	542
Ex Ghana/Cotton	D_1	335	435	183
	D_2	277	379	155
	D_3	434	388	205
Ex Bornu/Cotton	D_1	514	407	233
	D_2	222	379	155
	D_3	224	351	133
B. Local/Cotton	D_1	431	2571	643
	D_2	405	1959	513
	D_3	451	1904	517

Cotton was sown at 10-day intervals beginning on 12th June at Gusau, and 15 June at Konan Kuka. All cereals were sown on these dates.

Cotton yields were poor at Gusau, despite spraying, and sole cotton did not give a value which would compensate for the absence of early cereal. Cereal yields were variable but mixed cotton and cereal, when cotton was sown with the cereal was marginally more profitable than sole cereal.

Both millet varieties failed at Konan Kuka although mixture of cotton and millet were more valuable than the sole cereal. Where maize was concerned, despite only a moderate yield, sole cotton did not out-value sole maize. All mixtures of cotton and maize gave a greater cash return than sole cotton and cotton sown with maize was better than either sole cotton or maize.

Maize:Sorghum:Yam:Cowpea

These trials were designed with the object of determining whether yam could be successfully grown after maize and sorghum, or both mixed, without any staking other than stems of maize and sorghum; and whether cowpea could be successfully intercropped with yam in the second year. In each trial maize and sorghum were to be sown early, as normal, in each year, whilst yams were to be sown in November following harvest of the cereal. Cowpeas were to be intersown in July of the following year.

There were 8 replications of 3 treatments in 2 phases at each location. Treatments were:

1. Maize followed by yam; yam interplanted with cowpea the following year.
2. As above but sorghum in place of maize.
3. As above but maize and sorghum sown on alternate ridges.

The second phase consisted of the same treatments, but sown one year later.

Cereals and cowpea were to be sown 30 cm. apart on 91cm. ridges; whilst yams were to be planted 1.22m apart on the same ridges. Fertiliser to be applied at 300 kg. of compound 20:10:10 to cereals in each year, and the same amount to yams, when approximately $\frac{2}{3}$ of the yam have emerged, in the following year.

Abuja

The experiment was sown 6 June 1974 on freshly cleared land with O 96 maize and ME C 7-4-2 sorghum. There was no record of yam being planted.

Yields of both cereals were very poor due to excessive waterlogging and considerable erosion damage. Further yield loss was attributed to damage by monkeys.

Mean yields of grain were: 1826 kg. maize, 2414 kg. sorghum; and 1625 kg. maize plus 974 kg. sorghum $ha.^{-1}$ in 1974.

Because of waterlogging the experiment was shifted to a new location in 1975 where the objects of the experiment appears to have been lost since yams were planted in June before cereals, and cowpea interplanted in the same year as cereals. Further, yams appear to have been harvested in the same year as planted. Yields are given in Table A 47.

Table A 47.
Yields in kg. grain or fresh yam ha^{-1}

Treatment		Maize	Sorghum	Yam	Cowpea
Phase 1	(1)	-	-	6630	0
	(2)	-	-	4476	0
	(3)	-	-	5323	0
Phase 2	(1)	3713	-	-	0
	(2)	-	2785	4950	0
	(3)	3279	1625	4950	0

Cowpea completely failed to produce pods, whilst either yams were incorrectly planted in treatments 2 and 3 of phase 2 or were incorrectly entered in the logbook. It is noticeable that both maize and sorghum grown mixed yielded more than when grown sole; maize by 77% and sorghum by 17%.

Kabba

Yam planted in phase 1 was harvested on 15 October 1975. The latter (phase 2) should not have been harvested until late 1976. Yields are given in Table A 48.

Table A 48.
Yield in kg. grain and fresh yam ha^{-1}

Treatment		Maize	Sorghum	Yam	Cowpea
Phase 1	1	6314	-	38424	-
	2	-	5360	45340	-
	3	3088	4647	44818	-
Phase 2	1	2422	-	-	-
	2	-	4476	-	-
	3	2744	1192	-	-

(It is suspected that yields from phase 1 were harvested from the gross plot).

From trials where two years results are available the following general statements can be made.

1. Maize in mixed maize/Sorghum yielded an average of 34.7% more than sole maize, while mixed sorghum yielded an average of 19.0 more than sole sorghum.

2. Yam following maize averaged 18757 kg; following sorghum, 21247 kg, and following the mixture 20917 kg. ha^{-1}. It is unlikely that these differences are significant and maize appears as good as sorghum as a yam stake. However, because of the gain by cereals when grown mixed greater total returns will be obtained when yams are planted after mixed maize and sorghum.

Minna

This trial was sown with cereals in phase 1 on 20 June 1974; and cereals for phase 2 on 30 April 1975. Yams were planted on 29 April 1975 for phase 1; there was no record of cowpea being sown. Yields are given in TableA 49.

Table A 49.

Yields in kg. grain and fresh yam ha^{-1}

Treatment		Maize	Sorghum	Yam	Cowpea
Phase 1	1	4935	-	11217	0
	2	-	1826	13924	0
	3	2460	1438	12611	0
Phase 2	1	3837	-	-	-
	2	-	340	-	-
	3	2399	224	-	-

Bopo

Phase 1 of the trial was sown with 0 96 maize and SK 5912 sorghum on 17th July 1975 and with yam on 21 January 1976. Despite vigorous growth sorghum yielded nothing because of head smut. Mean yield from maize was 668 kgs. ha^{-1} from sole crop maize, and 365 kgs. from mixed maize.

Lafia

Maize, 0 96, and sorghum SK 5912, were sown on 29 April 1975 and yam planted on 23 February 1976. Yields were: Sole maize 2159 kg; grain; sole sorghum 503 kg. gresh head; 1387 kg. maize grain and 438 kg. fresh head.

Ilorin.

Sole maize, C 96, was sown on 10 June 1974; both sorghum, MF-C-7-4-2, and maize mixed with sorghum were sown 3 weeks later on 3 July 1974; yam was planted on 5 October 1974. Maize for phase 2 was sown on 9 May 1975, whilst sorghum was again sown later, on 10 June 1975. Cowpea was not sown because there appeared to be "no space" between yams.

Yam / Cowpea and Millet

These trials were designed to compare return from sole yam, yam intercropped with long season millet, and yam intercropped with long season millet and cowpea. A comparison between these treatments on both ridges and mounds was also included.

Yams were planted 1:22 m. apart on 1.22m ridges or in the centre of mounds 1.22m apart from other mounds in both direction.

Four stands of millet were sown either around the yam on the mound or between yam along the ridge. Cowpea was sown between millet on mounds or alongside millet on ridges.

Yields were poor, probably, because all crops were sown very late; 15 June 1976 for both yam and millet, and 22 July 1976 for cowpea. Yields in kg. fresh yam and kg. grain ha.$^{-1}$ are given in Table A 50.

Table A 50.

Yields as kg. grain and fresh yam ha.$^{-1}$

Treatment		Yam	Millet	Cowpea
Sole yam	R	2902	-	-
+ Millet	R	2006	244	-
+ Millet/Cowp	R	1743	236	-
Sole yam	M	2934	-	-
+ Millet	M	989	407	-
+ Millet/Cowpea	M	951	512	-

Cowpea and millet failed, whilst yam was harvested a year too soon.

Cereals, grounduts sown "gicci", together with cowpea

These trials were designed to demonstrate that sowing cereal "gicci" with groundnuts give greater cash returns than sole crop groundnuts, and that even greater returns can be obtained if cowpea is added to the mixture.

There were 9 treatments

1. Sole crop groundnuts
2. Sole crop groundnuts with stands missing at 1.37m intervals.
3. As 2, with maize (S.123) sown in gaps.
4. As 2, with sorghum (SK 5912) sown in gaps.
5. As 2, with maize and sorghum sown alternately in gaps
6. As 2, with cowpea sown on side of ridge by gap
7. As 3, with cowpea sown on side of ridge by maize
8. As 4, with cowpea sown on side of ridge by sorghum
9. As 5, with cowpea sown on side of ridge by maize/sorghum.

Groundnuts were given a basal dressing of 200 kg. ha.$^{-1}$ single superphosphate whilst each cereal stand was given 28 gr. nitrochalk, equivalent to 224 kg. ha.$^{-1}$ nitrochalk.

Katsina-Ala

Groundnuts, variety T28-204, were sown on 12 May 1975, whilst Maize and Sorghum were sown on 26 May 1975. Cowpeas were sown on 5 August 1975. Yields are given in Table A 51.

Table A51

Yield in kg. grain, shelled nuts, bean, cowpea ha^{-1}

Treatment	Groundnuts	Maize	Sorghum	Cowpea	Value ₦
Sole Groundnuts	370	-	-	-	95.54
Sole Groundnut - 137	336	-	-	-	85.85
G'nut + maize	340	133	-	-	93.35
" + sorghum	299	-	25	-	82.58
" + maize/sorghum	328	62	29	-	89.35
" + cowpea	303	-	-	100	101.43
" + maize/cowpea	299	179	-	33	105.18
+ Sorghum/cowpea	257	-	21	25	87.54
+ Maize/sorghum/cowpea	336	62	21	42	97.55

(Maize @ ₦10.02, Sorghum @ ₦11.19, Cowpea @ ₦21.65, G'nuts @ ₦25.55 per 100 kg.)

Groundnut yields were not affected by mixing and a mean figure was used for value.

Yields were very poor throughout and firm conclusions cannot be drawn.

Gagnum

All cereals (S.123 maize, SK 5912 sorghum) and groundnuts (var. not given) were sown on 19 mm 1975, cowpea was sown on 4 August 1975. Yields are given in Table A 52.

Table A 58

Yield in kg. grain, shelled nuts, and bean, ha^{-1}

Treatment	Groundnut	Maize	Sorghum	Cowpea	Value $
Sole G'nut	1385				353.87
Sole G'nut - 1.37	1219				311.45
+ maize	1060	924	-	-	365.08
+ sorghum	1141	-	166	-	310.10
+ Maize/sorghum	1162	377	132	-	350.12
+ cowpea	1[illegible]4	-	-	70	327.89
+ maize/cowpea	1090	962	-	81	376.62
+ sorghum/cowpea	1090	-	145	62	308.14
+ maize/sorghum/cowp.	951	453	187	66	324.40

Yields of cereals and cowpea were poor in both trials, nevertheless there was an indication that "gicci" maize plus cowpea may give greater returns than groundnuts alone.

B. Rotations and Sequences

Only one experiment, begun in 1972, is carried out under this head. The trial was designed to determine the best sequence in which to grow sorghum, cotton and groundnut.

Results until 1975 showed that the best sequence was groundnuts, sorghum and cotton, but also showed that regardless of sequence all crops showed a linear decrease with time. In 1976, therefore, plots were split for the following treatments.

Groundnuts

1 900 kg. line and 20 kg. P_2O_5, ha^{-1}
2 900 kg line and 40 kg. P_2O_5, $ha.^{-1}$
3 20 kg. P_2O_5 ha^{-1}
4 40 kg. P_2O_5 ha^{-1}

Sorghum and cotton

1 900 kg. line, 30 kg. N and 40 kg P_2O_5 ha^{-1}
2 900 kg. line, 40 kg. P_2O_5 ha^{-1}
3 40 kg P_2O_5 ha^{-1}
4 40 kg P_2O_5, 30 kg. N ha^{-1}.

Fertiliser application prior to this was 20 kg. P_2O_5 ha^{-1} to groundnuts; 33 kg N and 20 kg. P_2O_5 ha^{-1} to sorghum and cotton (corresponding approximately to those marked * in the following tables).

Table A 53

Yield of sorghum in kg. grain $ha.^{-1}$

Following	1972	1973	1974	1975	1976	
-	3095	-	-	-	-	
Sorghum		2474	2048	1236	1422	P + N
					1612	P + 0*
					1323	P + Line
					1490	P + N + Line
					1462	
Cotton		2982	2449	1886	2007	P
					1792	P + N*
					1931	P + Line
					1581	P + N + Line
					1805	
Groundnut		3563	2819	2071	2524	P
					2068	P + N
					2129	P + Line
					1611	P + N + Line
					2083	

Table A 54

Yield groundnuts as unshelled nut ha^{-1}

Following	1972	1973	1974	1975	1976		
-	3408	-	-	-	-		
Groundnut		1454	1231	367	1384	½P	*
					1522	P	
					1309	P + Line	
					1452	½P + Line	
Mean					1417		
Sorghum		2292	1344	523	1634	½P	*
					1712	P	
					1472	P + Line	
					1581	½P + Line	
Mean					1600		
Cotton		2181	1280	584	1363	½P	*
					1203	P	
					1330	P + Line	
					1352	½P + Line	
Mean					1312		

Table A 55

Cotton Yield in kg. seed cotton $ha.^{-1}$

Following	1972	1973	1974	1975	1976		
-	1545	-	-	-	-		
Cotton		1126	658	503	1759	P	
					1958	P + N	*
					1787	P + Line	
					1858	P + N + Line	
Mean					1840		
Sorghum		1584	933	851	1609	P	
					1025	P + N	*
					1253	P + Line	
					1545	P + N + Line	
Mean					1358		
Groundnut		1026	809	467	1631	P	
					1538	P + N	*
					1410	P + Line	
					1709	P + N + Line	
Mean					1572		

Table A54. shows mean yield, for treatment over all sequence, for 1976.

S + C	Sorghum	Cotton	Groundnut	G
P	1984	1666	1460	½P *
P + N	1794	1507	1479	P
P + Line	1794	1483	1370	P + Line
P + N + Line	1561	1704	1462	+P + Line

Yields of cotton appear to have recovered to those obtained initially, whilst groundnuts are back to the 1974 level. Yields of sorghum did not recover but stopped declining. Two what the reversal of the previous trend is due cannot be decided at this stage. No clear response to additional phosphate or line , compared with fertilisers given in previous years, was obtained.

SUB-PROGRAMME H.III Weed Control and Tillage

This sub-programme was reviewed on 7th April, 1977. The objectives and priorities were redefined and the priorities revised. The revised sub-programme was approved by the Professional and Academic Board on 29th June, 1977.

Extracts from the sub-committee minutes:-

"Objectives

To reduce or eliminate competition from weeds for at least seven weeks after the sowing of a crop, in the cheapest and most effective way in all farming systems, without reducing yield and with the main intent to reduce drudgery."

"Constraints

Where chemicals are used to control weeds they should not be toxic to mammals, or, if toxic, satisfactory safeguards must be ensured.

Such chemicals should not leave undesirable residues."

"Priorities

Although the main concern is the small farmer, the most immediate use for herbicides will be for large scale production farms, and all efforts should be made to be able to answer weed problems in these areas.

Immediate priorities for crops are;

(a) Control of weeds in the mixture millet/sorghum.
(b) Control of weeds in sole crops maize, cotton, groundnuts, millet and sorghum."

Project H.III/1. Weed control in the hoe farming system. The revised criteria for making recommendations in this Project are now:-

(a) Reduced weed competition measured by the 'logistic weed growth rate' (Ogborn, 1976) for at least 49 days compared with a timely weed CHECK treatment.
(b) No reduction in yield compared with the CHECK treatment.
(c) Herbicide residues tolerated in a pot bioassay or in hoe weeded test crops grown on the experimental site.
(d) The weed control input must be profitable at current prices.

Agronomic practice

All early sown crops are established on old (previous season's) ridges prepared by the minimum possible 'spot' hoeing. Late sown crops may be sown on split ridges.

When hoe weeding is needed, the whole ridge surface is cultivated.

Herbicide application

Methods of herbicide application practicable for the hoe farmer. The general shortage of water in the savannah zones during crop establishment precludes the use of orthodox high volume (200 l/ha +) herbicides applications. Manufactured granules broadcast by hand give good results but are expensive and not readily available. Mixtures of superphosphate and herbicide (herbilisers) broadcast by hand were compared with very low volume (VLV) applications at 10 l/ha in 1976.

Sub-project H.III/1/1 Weed control in the sorghum - millet mixture.
Researcher J.E.A. Ogborn

Experiment H.III/1/1/1

Comparison of herbiliser and VLV applications of liquron in the millet sorghum. cowpea mixture at Samaru.

The experiment was based on a crop mixture of alternative rows of millet and sorghum which were sown onto ridges left after the 1975 harvest.

Field Operations

12/4/76 linuron herbiliser treatment broadcast (and incorporated on some plots in error)

4/5/76 millet planted

5/5/76 1st application of VLV linuron

25/5/76 Hoe weeding started

26/5/76 sorghum planted

7/7/76 2nd application of VLV linuron

20/7/76 cowpea planted into the millet rows

28/8/76 millet harvest

25/11/76 cowpea picking started

13/12/76 sorghum harvest

There were several operational errors including a failure to apply nitrogen fertiliser. The final field layout included a non-orthogonal and unintentional contrast between plots which received only the characteristic 'minimum tillage' (=minimum hoeing) ridge preparation used by hoe farmers before sowing millet and a pre-plant cultivation of the ridge with an intermediate technology rolling cultivator.

Weed control with linuron was adversely affected by the presence of the perennial grass weed *Cynodon dactylon* which tolerates linuron.

The gross value of the total production from the crop mixture was not only reduced by the absence of fertiliser nitrogen but also by heavy damage done by birds to the earliest maturing plots of millet. As in previous years these were the plots receiving ppb linuron. The recorded millet yield response to linuron application was therefore an underestimate.

Fertiliser 1 quintal of superphosphate/ha either broadcast as herbiliser or side banded except that the 'overlap' treatment receiving 3.2 kg ai ha of linuron also received 2 quintal of superphosphate.

Table C.1. The effects herbicide formulation and seedbed treatment on crop yield and herbicide profitability

Seedbed prep.	minimum hoeing		rolling cultivation with oxen		
Linuron kg ai/ha	0	1.6	.8 + .8	1.6	3.2
Herb. applic.	-	ppb	VLV	ppi	ppi
Super. applic.	banded	brdcast	banded	brdcast	brdcast
Mill. grn. kg/ha	127	124	246	205	157
Sorghum. grn. kg/ha(sig)	110	192	299	581	812(.026)
Cowp. grn. kg/ha(sign)	310	272	264	188(.045)	114(.005)
Gross N value	155.79	158.68	222.90	201.30	233.56
Hoe labour hours/ha					
Crop estab. (7 weeks)	315	339	339	411	409
Mill. harv. (sig.)	312	281(.104)	166(.002)	365	402
End of rains	50	43	94	84	86
Hoeing costs N	145.21	142.04	128.42	184.24	192.11
Herbicide costs.	0	7.30	8.10	7.30	18.60
Herbicide profit	-	- 1.24	75.80	- .82	12.27
Days of weed suppression	-	62	126	72	62
Melon bioassay (sig)		+	-(.049)	-(.125)	-(.001)

Note. Millet and sorghum were valued at 20k/kg, cowpeas at 35k/kg and labour at 21.44k/man hour.

The results from the major treatment combinations are shown in table C.1. All linuron treatments produced some increase in gross crop value but both incorporated linuron treatments significantly reduced cowpea grain yields. Similarly both incorporated and the split VLV treatment left residues which were detectable by bioassay. The 3.2 dosage residue was large enough to endanger following crops. The 1.6 dosage residues were very small and unlikely to have any effect on sensitive crops.

Only VLV application reduced hoeing hours. The increases observed in the other treatments were due to the response of Cynodon dactylon to broadcast superphosphate. The total weed bulk and the equivalent 'L' values were reduced for periods exceeding 49 days from sowing.

Linuron at 1.6 units ppb reduced competition for more than seven weeks without reducing crop production or leaving detectable linuron residues. It is therefore formally 'recommendable', but unlikely to be attractive to farmers if applied to a site infested with Cynodon dactylon with no nitrogen fertiliser. The split VLV application of linuron appears to be very profitable when applied to a cultivated seedbed and should give good results in the animal power farming system.

Current recommendation. None.

Proposed recommendation for the Samaru area, all herbicide dosages as kg ai/ha.

1. Linuron at 1.6 units pre-plant broadcast as herbiliser to millet on 100 kg single superphosphate/ha. Cynodon dactylon should be absent and the crop should received nitrogen fertiliser.

Experimental series H.III/1/1/2. Zonal testing on sole crop millet.

Eight experiments were proposed for 1976. The experiments at Wailo and Lokogoma were not established. The final results for Maiduguri are not yet available. The experiments at the remaining five sites are summarised below.

The herbicides were to be broadcast as superphosphate 'herbiliser' on unprepared ridges remaining after the 1975 harvest. The millet was to be sown on 1st May (or immediately after the first moderate rainfall). Detailed instructions were given about crop establishment and hoe weeding but in only one case were they adhered to exactly in spite of regular junior staff touring from IAR. Nevertheleass the experimental technique is remarkably error resistant and clear experimental conclusions were obtained in all the five experiments reviewed below. Weed weights were recorded and show that the herbicides definitely reduced weediness but this did not in general affect the hoe weeding effort at the farm centres mainly because of failure to perform the prescribed weeding routine. The effect of reduced weed competition was therefore mainly shown as increased yield.

Table C4.1. Millet herbicides. Zonal testing in the hoe farming system

Herbicide dosages kg ai/ha. Grain yields kg/ha

Herbicide treatment	(hoeing only)	linuron 1	linuron ½	progazine 1
Sudan zone				
Tambu 1975 - 6				
1975 dosages	-	3.2 *	1.6 *	-
Grain yields	205	95(.003)	147(.057)	-
1976 dosages	-	0.8 *	0.4	0.4
	3336	2854(.045)	3324	3203(.310)
Ladanawa 1976				
1976 dosages	-	0.8 *	0.4	0.4 *
Grain yields	33	398(.041)	387(.073)	313(.255)
Potiskum 1976				
1976 dosages	-	0.8	0.4	0.4
Grain yields	1159	1366(.181)	1216	1127
Northern Guinea				
Rano 1975, Dangora 1976				
1975 dosages	-	3.2 *	1.6	-
Grain yields	757	510(.083)	689	-
1976 dosages		1.6	0.8	0.8
Grain yields	1483	1639(.166)	1605(.029)	1664(.131)
Riverain area				
Mbatie 1976				
1976 dosage	-	3.2 *	1.6	1.6 *
Grain yields	201	213	166(.033)	265(.001)

Note 1. The figures in brackets indicate the '1-tailed' significance of the difference from the 'hoeing only' treatment

Note 2. The residues of dosages marked '*' were detected by melon bioassay in soil sampled at the end of the rains.

The results in table 1. indicate clearly that selective dosages in the Sudan zone are in the range 0.4 kg ai/ha or less. Even this level was too high at Tambu where 0.4 units did not increase yields in an exceptionally high yielding and accurate experiment. The results at Potiskum appear to indicate that the dosages could be higher. This is confirmed by the absence of residues detectable by 'egusi' melon bioassay.

In the Northern Guinea zone where 1.6 kg ai/ha has already been identified as the selective dosage for Samaru and Birnin Gwari, the same dosage gave an increased yield at Dangora in 1976 and a small reduction at Rano in 1975. It would appear that 0.8 units is the most profitable dosage in the Rano - Dangora area.

The first result from the Riverain area appears to indicate that limuron is not selectively active at this site whereas propazine has given a significant yield increase. This would be expected with the higher rainfall and greater proportion of broadleaved weeds in the flora.

The results from the northern sites in 1975 - 6 show a very marked correllation between the selective dosage and clay content (Table 2).

Organic matter contents appear to be very low in all the experimental sites and this does not appear to be an important variable affecting herbicide activity. The influence of seasonal rainfall can only be determined by further seasons of testing with the selective dosages.

Table 4.2. Probable selective dosages of limuron related to clay content.

Site	Clay %	Dosage kg ai/ha
Tambu	4	0.4
Ladangwa	4	0.4
Rano	10	0.8
Samaru	12	1.6
Birnin Gwari	12	1.6

Sub-project H.III/1/2 Weed control in sole crop cotton. Researcher, J.E.A. Ogborn.

Experiment H.III/1/2/2

Comparison of herbiliser and VLV applications of diuron and dalapon in sole crop cotton at Samaru.

The herbicides were broadcast pre-plant to June sown cotton on unprepared ridges. The ridges were split prior to July planting in the 'hoeing only' check treatments.

The main objective was therefore to compare 'farmers practice' July sown cotton with 'minimum tillage' cotton sown in June.

Field operations

9/5/76	Herbiliser treatments applied on 1 quintal of boronated SUPA/ha
19/6/76	VLV treatments applied.
15/6/76	Hoe weeding started.
23/6/76	Herbicide treatments sown
1/7/76	Ridges split over 1 quintal of boronated SUPA/ha
6/7/76	'Hoeing only' treatments sown. Boronated SUPA side-banded on VLV treatments.
30/8/76	Cotton spraying started
1/9/76	Urea side banded on all treatments at 1 quintal/ha
23/11/76	Cotton picking started.
10/2/76	Cotton picking completed.

Results

Recommendable treatments

The results in table C.3 show that all the June sown minimum tillage herbicide treatments reduced weed growth rate for more than seven weeks but treatment 8 had a yield which was non-significantly below the range of the July sown 'farmers practice' checks. With this exception therefore, all the herbicide treatments were 'recommendable'.

Table C.3 Crop yields and duration of weed suppression in hoe farmers cotton at Samaru 1975

Treatment	Herbicide diuron	Kg ai/ha. dalapon	Hoeing mode	Seed cotton kg/ha	Days of weed suppression
7	0.8	2.0	timely	1553(.004)[1]	99
2	0.4	0	timely	1502(.006)	161
1	0.8	0	timely	1179(.126)	161
4	0.8	0	late	1107	99
6	0.4	0(V)[2]	late	1097	99
10	0.8	2.0	late	1030	99
3	0.4	0(V)	timely	964	99
11	0.4	2.0	late	938	99
12	0.4	2.0(V)	late	923	99
5	0.4	0	late	923	99
9	0.4	2.0(V)	timely	789	99
CHECKs	0	0	timely	953	-
8	0.4	2	timely	738(.136)	99

Notes.

1. Values in brackets indicate the significance of treatment means outside the range of the CHECKs.
2. (V) herbicide applied in 10 l/ha with a VLV applicator. The other treatments were applied as herbilisers.

The 'cheapest and most effective treatments'.

The results in table C.4 show that in 1976 6 out of 11 recommendable treatments would have been profitable.

Table C.4 Economic responses to herbicide use

Treatment	Cost of herbicide N	Labour hours/ha	Crop response kg/ha	Profit from herb N/ha
7	8.37	819	600	216.44
2	1.37	635	548	246.32
1	3.65	1413	226	- 29.64
4	3.65	1062	154	30.80
6	1.82 (V)	970	144	49.25
10	8.37	724	77	74.67
3	1.82 (V)	982	10	5.14
11	6.54	961	- 15	- 2.83
12	6.54 (V)	1012	- 31	- 18.72
5	1.82	852	- 31	- 20.30
9	6.54 (V)	837	-164	- 22.43
CHECKs	0	1000	-	-
8	6.54	1413	-215	-161.74

Note: Labour and seed cotton costed at N.2144/hour and N.31/kg respectively.

Table C.5. shows that 'delaying' hoe weeding had a very small proportionate effect on total weeding hours, reducing costs by N19.72. This was accompanied by a small reduction in crop yield which resulted (Table C.6) in a reduction in profitability of N23.54.

Table C.5. Treatment effects on hoeing manhours/ha

Herbicide treatment diuron	/ dalapon	Hoe weeding mode timely	delayed	means
0.8	0	1448	1062	1255
0.4	0	635	852	744
0.4	0 (V)	982	970	976
0.8	2.0	819	724	772
0.4	2.0	1413	961	1187
0.4	2.0 (V)	837	1012	924
Means		1022	930	976
CHECKs		1000		

Table C.6. Treatment effects on herbicide profitability (N)

Herbicide treatment diuron	dalapon	Hoe weeding mode timely	late	means
0.8	0	- 29.64	30.80	.58
0.4	0	246.32	-20.30	113.00
0.4	0 (V)	5.14	49.25	27.20
0.8	2.0	216.44	74.67	145.56
0.4	2.0	-161.74	-2.83	-82.28
0.4	2.0 (V)	- 22.43	-18.72	-20.58
Means		42.35	18.81	30.58

Table C.6 also shows that herbicides gave an average profitability of N30 when labour is costed at the 'farmers rate' of 21.44 kobo/hour. The average profitability would have been higher if labour had been charged at the 'government rate' of 27.1 kobo/hour.

The combination of 0.4 diuron + 2.0 dalapon was clearly unprofitable whereas 0.4 diuron or 0.8 diuron + 2.0 dalapon were profitable. Either of these two herbicide treatment can therefore be recommended for Zaria with the latter preferred for sites where Cynodon dactylon is present. This grass is not controlled by soil applied diuron but can be suppressed by timely hoe weeding.

The actual mean hoe weeding treatments are shown in table C.7.

Table C.7. Weed control cultivations in hoe farmers cotton at Samaru 1976
(Weed wt as kg dm/ha. Hoe time as hours/ha)

Treatment			Hoeing	1st cultivation			2nd cultivation			3rd cultivation.		
No.	diuron	dalapon	mode	date	wt.	hours	date	wt.	hours	date	wt.	hours
7	0.8	2.0	timely	19/6	2953	308	31/7	602	336	22/8	342	175
2	0.4	0	timely	18/6	2782	315	29/7	681	266	13/9	250	54
1	0.8	0	timely	18/6	2980	501	23/7	755	557	3/9	995	390
4	0.8	0	late	15/6	3829	588	24/7	1070	228	1/9	635	246
6	0.4	0(V)	late	16/6	795	476	26/7	917	308	24/9	1096	186
10	0.8	2.0	late	17/6	1662	347	1/8	887	144	30/8	84	233
3	0.4	0(V)	timely	19/6	3072	441	27/7	687	511	3/9	149	30
11	0.4	2.0	late	16/6	2437	319	29/7	1079	378	11/9	494	264
12	0.4	2.0(V)	late	25/6	2529	490	20/8	1149	95	7/10	455	427
5	0.4	0	late	15/6	3829	376	28/7	851	368	4/9	311	113
9	0.4	2.0 (V)	timely	3/7	2875	483	20/8	1290	242	15/9	24	112
CHECKS			(Ridge splitting)			413	3/8	932	190.	16/9	925	397
8	0.4	2.0	timely	18/6	3593	581	24/7	624	343	28/8	288	489

The first hoeing was the 'establishment cultivation' and was timely in all treatments. The table reveals that the delay imposed at the second weeding had very little effect in delaying the third weeding even though the 'late' plots were in fact delayed after they were marked as 'ready for weeding'. These results confirm that the hoe farmer gains no profit and does not reduce his total weeding task by delaying the weeding of cotton in the presence of herbicide.

It was also noteworthy that the very low volume herbicide applications which gave spectacular early weed control, did not prove to be highly profitable.

1976 was one of the worst seasons so far experienced for herbicidal weed control on hoe farmers cotton. Early and heavy rains produced vigorous weed growth on herbiliser treated ridges, while the thorough wetting of the checks reduced the effort normally required to split them. The late continuation of the rains at the end of the season also reduced the normal yield response to June sowing. The profit from using herbilisers would therefore be greater in most seasons.

Current recommendation. None

Proposed recommendations for the Samaru area, all herbicide dosages as kg ai/ha.

1. Diuron 0.8 + dalapon 2.0 applied as herbilisers on 100 kg single superphosphate/ha. When Cynodon dactylon is present.

2. Diuron 0.4 applied as herbilisers on 100 kg single superphosphate/ha f[illegible]

Experimental series H.III/1/2/2e. Zonal testing in sole crop cotton.

This series was started in 1974. The first two seasons were mainly used to determine the optimum dosages of herbicide. The 1976 experiments used dosages which were expected to be profitable and recommendable.

The main experimental comparison was to compare July sowing on split ridges (the most frequent mode of crop establishment) with June sowing on an unprepared seedbed which had received a pre-plant-broadcast application of herbicide. July sown herbicide treatments were also included. Diuron which is the cheapest and oldest cotton herbicide was compared with norflurazon which has activity against established weeds and sedges for June sowing.

A set of very low volume treatments was also included in the series but applicator defects reduced their reliability. Only the results from the herbiliser treatmtns are therefore presented.

All herbicide dosages are expressed as Kg ai/ha. All seed cotton yields are expressed in kg/ha. All cotton received four insecticidal sprays. The crop was otherwise grown according the 'Recommended Practices'. The statistical significance of differences between herbicide treatments and the July sown CHECKs are presented in the following tables in brackets.

Bopo, Benue State Derived Savannah Zone. Herbiliser applied 26/4

Table 1221. Pre-plant broadcast herbilisers on cotton at Bopo, 1976

	Seed cotton	Days of weed suppression	Millet bioassay	Herbicide profit/ha
June sown 15/6				
diuron 0.8	411(.051)	79	detected(.021)	N36.34
diuron 1.6	409(.049)	79	detected(.026)	N32.07
norflurazon 0.8	376(.113)	79	detected(.084)	N18.80
norflurazon 1.6	581(.000)	79	detected(.069)	N72.02
July sown 6/7				
diuron 0.8	171(.077	14	detected(.008)	-N38.06
diuron 1.6	205	14	tolerated ?	-N31.17
CHECK (ridges split 21/6)	282	-	-	-

It was not practicable to measure labour inputs directly at Bopo. The June sown herbiliser treatments had a light weed cover at sowing time whereas the July sown crop had to be sown into plots covered with vigorous established weeds. The weed growth rate on the June sown treatments was reduced until the 2nd September.

The herbicide residues from both diuron and norflurazon were detectable in the soil samples assay, the diuron residues being more damaging to millet than norflurazon. Until the status of these residues can be clarified by test cropping in the field at Bopo it will not be possible to make an unrestricted recommendation, but there is now a clear indication of the most effective dosages to be used in monocrop cotton.

The yield reductions and negative profitability indicate that June sowing is the only crop for which pre-plant-broadcast applications are of practical use.

This was a very well conducted experiment in which all the experimental instructions were correctly performed!

Current recommendation. None

Proposed recommendation for sole monocropped hoe farmers cotton Bopo area.
Diuron 0.8 kg ai/ha pre-plant-broadcast as herbiliser on 125 kg of superphosphate/ha.
Norflurazon 1.6 kg ai/ha pre-plant-broadcast as herbiliser on 125 kg of superphosphate/ha.

Gusau, Sokoto state. Northern guinea savanna zone. Herbiliser applied 2/4

Table C Pre-plant broadcast herbilisers on cotton at Gusau, 1976

	Seed cotton	Days of weed suppression	Millet bioassay	Herbicide profit/ha
June sown 15/6				
diuron 0.4	947(.004)	93 +	tolerated	N113.53
diuron 0.8	934(.005)	93 +	detected(.161)	N109.50
norflurazon 1.6	1005(.001)	93 +	detected(.043)	N114.49
norflurazon 3.2	946(.004)	93 +	detected(.043)	N 75.53
July sown 6/7				
diuron 0.4	653	18	detected(.161)	N24.22
diuron 0.8	703(.154)	18	detected(.039)	N37.89
CHECK (ridges split on 30/6)	569	-	-	-

The experiment was basally weeded on all plots on 16/9 disregarding experimental instructions. The weed weights indicate that some norflurazon plots were weeded unnecessarily.

All herbiliser treatments yielded better than the CHECKs. June sown diuron 0.4 also left no detectable residues. This treatment is therefore 'recommendable' without restrictions. Norflurazon 1.6 gave a slightly higher yield and a comparable profit but left significant herbicide residues. It can be recommended for monocropped cotton because of its activity against sedges. This experiment was reasonably well performed, but the weeding instructions were neglected.

Current recommendation
None.

Proposed recommendation, for sole cropped hoe farmers cotton Gusau area. Diuron 0.4 kg ai/ha pre-plant broadcast as herbiliser on 125 kg of superphosphate.

Mokwa, Niger state, Southern guinea savanna zone. Herbilizer applied 29/4

Table Pre-plant broadcast herbilisers on cotton at Mokwa, 1976

	seed cotton	No of hoe operations	Millet bioassay	Herbicide profit /ha[2]
June sown 14/6				
diuron 0.4	1073(.000)	3.00	tolerated	N192.37
diuron 0.8	1053(.000)	2.69(.043)	tolerated	N188.14
norflurazon 1.6	1385(.000)	2.32(.003)	detected(.015)	N278.55
norflurazon 3.2	1088(.000)	2.36(.004)	tolerated(.011)	N165.32
July sown 8/7				
diuron 0.4	411	2.68(.040)	detected(.065)	-N5.94
diuron 0.8	419	2.36(.004)	tolerated ?	- N4.37
CHECK (ridges split on 5/7)	482	3.25[1]	-	-

Notes. 1. Includes ridge splitting
2. Uses labour costs derived by D.J. Ogungbile at Yola.

The weeding operations were correctly performed at Mokwa, enabling a notional value for weed control costs to be included in the profitability calculation. They are comparatively unimportant compared with the yield increases obtained from June sowing. All June sown herbicide treatments gave more than seven weeks post sowing weed control. The diuron left no detectable residue at either dosage. The most profitable treatment was norflurazon at a dosage of 1.6 but this left significant residues. Either dosage of diuron is recommendable and gave comparable profits. The lower dosage is safer and is to be preferred.

Current recommendation.

None.

Proposed recommendation for sole cropped hoe farmers cotton Mokwa area

Diuron at 0.4 kg ai/ha pre-plant-broadcast as herbiliser on 125 kg of superphosphate.

Saminaka, Kaduna state, Northern guinea savanna zone. Herbiliser applied 30/4

Table Pre-plant broadcast herbilisers on cotton at Saminaka, 1976.

	seed cotton	Days of weed suppression	Millet bioassay	Herbicide profit/ha
June sown 18/6				
diuron 1.6	604	not	detected(.138)	N9.13
diuron 3.2	750(.034)	recorded	'tolerant' ?	N47.10
norflurazon 1.6	775(.022)		detected(.092)	N47.84
norflurazon 3.2	812(.010)		detected(.113)	N39.57
July sown 6/7				
diuron 1.6	625		detected(.102)	N15.95
diuron 3.2	643		detected(.113)	N13.93
CHECK (ridges split on 14/6)	551			

This site is weedier than most cotton growing areas. A so far unidentified Brochiaria sp appears to be resistant to low rates of both diuron and norflurazon. The higher rates of diuron used in 1976 apparently gave satisfactory weed control but this cannot be confirmed owing to operational errors.

All dosages of herbicides left detectable residues (the apparent tolerance to diuron 3.2 is almost certainly a chance result) and no unrestricted recommendation can be made until the status of the residues is determined directly by test cropping at the experimental site.

It is probable that mixtures of diuron with less persistent herbicides will eventually be recommended for the Saminaka area.

Current recommendation

None.

Proposed recommendation for sole monocropped hoe farmers cotton Saminaka area.

Norflurazon at 1.6 kg ai/ha pre-plant-broadcast as herbiliser on 125 kg of superphosphate.

Lemu, Niger state, Southern guinea savanna zone. Herbiliser applied 15/4

Table Pre-plant broadcast herbilisers on cotton at Lemu, 1976

	seed cotton	Estimated days weed suppression	Millet bioassay
June sown 15/6			
diuron 0.4	not	51	tolerated
diuron 0.8	recorded	43	tolerated
norflurazon 1.6		50	tolerated
norflurazon 3.2		53	tolerated
July sown 6/7			
diuron 0.4		0	tolerated
diuron 0.8		0	tolerated
CHECK (ridges split on 4/7)		-	-

A slovenly conducted experiment. Only one set of weed weights were recorded. These have been used to extrapolate minimum periods of weed suppression. The insecticidal spraying was inefficiently done and resulted in a partial crop failure. The site was inspected shortly before harvest when a poor crop was ready for picking but neither seed cotton or stalk weights were subsequently recorded. The experimental site was waterlogged during the rains and was probably not representative of the typical cotton land of the area.

This experiment was an expensive waste of resources.

Current recommendation

None.

Proposed recommendation for sole crop hoe farmers cotton, Lemu area.

None possible.

Table Probable selective dosages of diuron and norflurazon related to clay content.

Site	Clay %	dosage kg ai / ha diuron	dosage kg ai / ha norflurazon
Lemu	6	0.4	1.6
Gusau	8	0.4	1.6
Mokwa	10	0.4	1.6
Samaru	12	0.4	?
Bopo	14	0.8	1.6
Saminaka	20	3.2	3.2

The results in table indicate that a uniform recommendation of 0.4 units of diuron or 1.6 units of norflurazon may apply to most of the uplent cotton areas. At Saminaka, the very high dosage of diuron is almost certain to leave undesireble residues and is therefore unlikely to be recommended.

The major benefit from using preeplant herbilisers on cotton is that it permits early planting without ridge splitting. Some hoeing normally needs to done a few days after the crop has germinated.

Early weed control with herbiliser s was less good in 1975-6 than in 1973-4 apparently because the Kaduna superphosphate now used for herbilisers has much larger granule size than the imported grade previously used. In 1977, a mixture of powdered rock phosphate and herbicide has been tested and appears to give improved weed control.

The most promising development however, appears to be the use by hoe farmers of a 'ground-metered, shrouded disc' VLW sprayer which is simple to use, almost eliminates drift and applies the spray volume require. An application of 0.8 units of diuron and 2.0 units of dalapon in early May on unprepared ridges was still controlling weeds in cotton during the first week of August without any supplementary hoe weeding.

Subproject H III/1/3. Zero- tillage in the hoe farming system.

Experiment H III/1/3/1.

Zero-tillage on basement complex soils in the Northern Guinea savannah. Samaru. Researcher, J.E.A. Ogborn.

This investigation was in its 7th season in 1976. It was based upon the idea of controlling weeds by using herbicides without primary cultivation and supplementing their action by surface hoe 'scraping'. The crops were sown on the flat and all crop residues were left on the soil surface to prevent runoff and erosion. A detailed review of the results to date is not yet complete but it is already clear that the technique is not well suited to the Samaru environment.

The experience of successful zero-tillage in mechanised systems using contact active herbicides is that the weed challenge decreases as the weed seed reserves in the soil surface are exhausted by the first few seasons of chemical weed control. It is then sometimes possible to stop using herbicides for several seasons until the weed infestation builds up again. Table C4 shows that while the weed challenge undoubtedly does decrease with continuous zero-tillage, the actual labour inputs are of the same order as conventionally grown crops.

Only the cotton figures are strikingly less than the values for conventionally grown crops on adjacent sites but it should be remembered that the zero-tillage crops not only received a heavy input of herbicide but was also sown ' ' a square spacing of 46 cm. This is technically more difficult and more ..ourious for hoe farmer than conventional ridge

Table C 4 Hoe labour hours/ha required to control weeds in zero-tillage

Season of zero-tillage	7th	5th	3rd
Crop			
Maize	517	700	1090
Sorghum	638	884	956
Cotton	358	387	429

planting at the equivalent stand. The crop yields need to be considerably higher than conventional to justify the use of the zero-tillage technique and, more important, they should tend to increase with time. The results in table C 5 show that only maize yields increased with age of zero-tillage during 1974 - 6.

Table C 5 Mean yields of zero-tillage crops in the hoe farming system from 1974 - 1976.

Zero-tillage started	1970	1972	1974
Crop			
Maize	2700	2550	1920
Sorghum	1780	1840	1920
Cotton (74 - 5 only)	1021	968	1302

The technique may be more successful in lighter soils with weaker weed competition and it will be tested in the Sudan zone whenever this becomes noticable.

Current recommendation

None.

Proposed recommendation

None.

Reference Ogborn, J.E.A. (1976) 'The analysis of weed growth in hand hoed experiments' Proc. 1976 BCP conference weeds.

Project H.III/2. Weed control in animal powered farming systems

The objectives in this project are to reduce hand hoeing, to increase the utilisation of animal power and to improve profitability.

Sub-project H.III/2/1. Straddle - ridge cultivation.

This sub-project aims to develop a package of agronomic practices to optimise weed control with the straddle row rotary cultivator, now being developed at Samaru. Apart from the improved accuracy derived from the straddle row technique, the package also includes pre-plant ridge cultivation with the option of incorporating herbicides followed by drill sowing (with a hand metered sowing tube).

The system is particularly useful for heavy land areas where the land is usually too dry to split the ridges before sowing early planted crops.

Experiment H.III/2/1a. Researcher, J.E.A. Ogborn.

Straddle-ridge cultivation weed control in sole crop cotton. Samaru. The objectives of this experiment were (1) to compare the incorporation of trifluralin herbiliser on old ridges in April with incorporation on ridges split in June. (2) To compare 0.4 units of trifluralin with 0.8 units. (3) To assess the suitability of a prototype rotary cultivator for seedbed preparation and post-emergent weed control.

The prototype cultivator was not developed to cultivate the whole ridge and could not therefore be used for herbicide incorporation. This operations had to be done with a hastily adapted model of the original straddle row rotary made by Mr. Boyd of ITDG in 1973.

Field operations

9/4/76	Trifluralin herbiliser incorporated on old ridges. (1 quintal SUPA/ha)
2/5/76	Rotary cultivation of old ridges started.
15/6/76	Ridges split on remaining treatments.
23/6/76	Trifluralin herbiliser incorporated on split ridges.
23/6/76	Cotton drilled through hand metered sowing tube on a Boyd rotary cultivator.
7/7/76	Hoe weeding started on the tops of the ridges.
30/8/76	Nitrogen fertiliser applied at flowering. (1 quintal Nitra/ha).
21/9/76	Insecticidal spraying started.
13/13/76	Cotton picking started.
2/2/77	Cotton picking complete.

The results of the experiment on weeding requirement and seed cotton are set out in table C.9. All treatments received a total of 1 quintal of SUPA in the seedbed and 1 quintal of nitra sidebanded at first flower.

Table C 9. Effect of weed control treatments on seed cotton yields and hoeing hours in straddle row cultivation at Samaru

Trifluralin dosage kg ai/ha	Cultivation dates	Hoeing in hours/ha June-July	Hoeing in hours/ha Aug.-Oct.	Seed cotton kg/ha	Herbicide profit/ha
Herbiliser incorporated on old ridges 9/4/76					
0.4	(2/5, 27/5 -	199	507	887(.264)	N25.56
0.8	- 6/7, 30/8)	166(.220)	493(.241)	1081(.032)	N95.78
Herbicide incorporated 23/6 on ridges split 15/6/76					
0.4	(23/6, 6/7 -	247(.030)	518	875(.294)	N 9.20
0.8	- 30/8)	210(.220)	466(.044)	940(.161)	N48.43
Split ridges only (means of 2 treatments)					
0	(23/6, 6/7,30/8)	188	510	799	-
S.E. mean		± 22.5	± 57.7	± 110.0	

Note. Figures in brackets express the exact '1 - tailed' significance of the difference from the 'Split ridges only' treatment mean.

The conduct of this experiment was complicated by the presence of a heavy infestation of the perennial stoloniferous grass Cynodon dactylon (kiri - kiri). This was partially suppressed by the ridge-splitting in June but the rotary cultivators not only were unable to control the vegetative growth but also dugout and replanted some of the weed which had been buried by the ridge splitting. Consequently the early weed growth in June and July needed more man hours for control on the herbicide treatments than on the 'splitting only' treating.. The two rotary cultivations in May on the old ridges in rather drier conditions did give some control of cynodon and detectably reduced the hoeing required in June and July.

Only the 0.8 dosage gave detectable weed control after July and this late weed control was associated with detectably increased yields. The 0.8 dose on which reduced hoe weeding from June to October and increased yields markedly was definitely profitable.

Early weed control will undoubtedly be improved as better incorporation equipment is developed. The equipment so far available is not able to work efficiently in the presence of trailing grasses.

Current recommendation

None.

Proposed recommendation for animal power farmers sole crop cotton.

0.8 units of trifluralin broadcast as herbiliser on 125 kg superphosphate/ha incorporated pre-plant.

This recommendation cannot be implemented until suitable incorporation equipment is available for farmers use.

Best Available Document

Experiment H.III/2/1b. Researcher, J.E.A. Ogborn.

Weed control in animal power farming systems.

Straddle - ridge cultivation weed control in sole crop groundnuts.

The objectives of this trial were (1) to compare banded trifluralin herbiliser with broadcast trifluralin and a no herbicide check. (2) To observe the effects of the different proportions of placed superphosphate resulting from these treatments.

Field operations

27/5 - 2/6/76	Site prepared by ridging followed by 1 pass with the Boyd prototype Samstrad.
4 - 5/6/76	Application of herbiliser treatments and placed superphosphate all at 100 kg SUPA/ha.
21/6/76	Groundnuts planted by hand.
13/7 / 76	Rotary weeding started with the Oni prototype Samstrad.
4/8/ 76	Hoe weeding started.
8/10 /76	Groundnuts harvested.

Table C 8. Cultivations, hoeings and yields from groundnut production plots in the animal power system

Treatments.	Trifluralin dosage ppi kg ai/ha	Samstrad cultivation dates	Hoeing man hours/ha in Aug.- Sept.	Groundnuts in shell kg ha	Herbicide profit.
No herbicide					
100% placed SUPA	0	16/7, 30/7	302	890	-
Banded herbiliser 80% placed SUPA	0.16	17/7, 2/8	304	994(.174)	N33.56
Broadcast herbiliser 0% placed SUPA	0.80	16/7, 2/8	241(.048)	859	-N 2.39
Standard errors			± 23.7	± 97.1	

Note. The values in brackets express the exact significance of the treatment difference from the 'no - herbicide' treatment.

The straddle row cultivations are not optimal because they were performed with a prototype still under development, which was also not under full experimental control. They did however, eliminate the need for all hoe weeding during June and July.

The broadcast herbiliser treatment reduced hoeing man hours significantly but did not increase yields. The banded herbiliser did produce a small increase in yields but did not reduce hoeing man hours.

These results confirm the 1975 result that for groundnuts, broadcast herbiliser treatments yield less than those where some of the SUPA is placed below the seed.

Future experiments in groundnuts will therefore be based on the use of superphosphate placed below the seed combined with some method of herbicide application which does not involve the use of a SUPA carrier.

Project H.III/3. Mechanised weed control

The development of large scale crop production schemes requires a limited research programme to ascertain the correct herbicide dosages for each ecological zone and to compare cultivation techniques developed overseas.

Sub-project H.III/3/1. Partial mechanisation.

Main objectives:- 1. To develop herbicide applications on tractor prepa seedbeds which eliminate hoe weeding without unprofitable reductions in crop yields or post-emergent tractor cultivations.

2. To develop crop rotations which tolerate the activity of residues of the herbicides applied to the preceeding crop.

3. To identify methods of herbicides application most suitable for Nigerian conditions.

Presentation of results.

There are a large number of experiments included in this project in which the seedbed preparation and basal hoe weeding are supplemented by herbicides or additional hoe weeding. The major interest is therefore the profitability of the supplementary weed control inputs. The actual effectiveness of the herbicides for weed control was usually recorded, but is omitted form this presentation.

Experimental series H.III/3/1a. Weed control in groundnuts.
Researcher, W.B. Ndahi.

The objective of the series was to identify the optimum dosage of alachlor at Kano, Samaru and Mokwa.

The Mokwa trial failed to establish.

Treatments

Herbicide - Alachlor at 6, 3, 1.5 and 0 kg ai/ha.

Sites.

Kano and Samaru

Plot size = $\frac{\text{ha}}{454.5}$

Field operations	Kano	Samaru
Seedbed preparation	Tractor ridges	Emoet splitting
Date	8/6	16/5
Groundnuts planted	12/6	20/5
Herbicide applied pre-em.	12/6	20/5
Check treatment weeded	10/8	8/7
Groundnuts harvested	2/11	5/10

The 'weeded' CHECK treatment was hoe weeded once. All other treatments received no hoe weeding at all.

Table H.III/3/1ai. Effect of alachlor dosages on groundnut yield and profit at Kano and Samaru, 1976.

Treatment	Dosage kg ai /ha	Kano G. N. kernels kg/ha	Kano Weed control profit/ha	Samaru G. N. kernels kg/ha	Samaru Weed control profit/ha
Alachlor	1.5	97.0	N1.30	426.9	N13.17
Alachlor	3.0	132.3	N2.06	427.3	N16.63
Alachlor	6.0	206.0	N5.11	658.0	N52.90
Weeded CHECK		219.2	N4.49	543.2	N33.43
Unweeded CHECK		60.6	-	326.2	-
S. E.		±53.1		±23.6	

The cost of a single handweeding was estimated at N74.13/ha and was probably an underestimate. Alachlor is costed at its current price of N11.16/kg ai/ha. ex Kano. Yields at Kano were reduced by rosette. Nevertheless, profitability was highest at the highest recommended dosage of alachlor. No residue problems have been observed with this herbicide on mechanised seedbeds.

Current recommendation

None.

Proposed interim recommendation for partially mechanised sites in Kano and Samaru areas.

Alachlor at 6.0 kg ai/ha applied pre-emergent in high volume.

Experiment H.III/3/1b. Comparison of proprietry herbicides formulations for weed control in Maize at Mokwa.

Researcher, S. Lagoke

Site: Mokwa Research Station
Maize Variety: 096.

Main treatments were flat planting and rip planting with subsequent moulding up for ridging. The minor treatments consisted of three rates (1, 2 and 3 kg ai/ha) of four commercial herbicide formulations all applied pre-emergence in 10 litres of water per hectare, 2 hardweeding treatments (3, 6 weeks and 3, 6, 9 weeks after planting) and an unweeded check. These four herbicide formulations contained varying proportions of atrazine metolochlor and simazine.

Table H.III/3/1/b1. Grain yield and profitability of weed control practices in maize at Mokwa, 1976.

herbicide dosage kg ai/ha atrazine	metolochlor	simazine	Maize grain yield kg/ha sown on flat	ridges	Mean	Weed control profit
1.0	0	0	4789	4846	4818	N226.98
2.0	0	0	4542	4815	4678	N184.92
3.0	0	0	4355	4105	4230	N 68.58
0.5	0	0.5	4101	3649	3875	N- 0.12
1.0	0	1.0	5486	3425	4455	N129.60
1.5	0	1.5	4604	4516	4560	N145.60
0.4	0.6	0	3987	4492	4239	N 81.96
0.8	1.2	0	5103	4129	4616	N157.32
1.2	1.8	0	4052	4326	4189	N 39.84
0.5	0.5	0	4488	4242	4365	N112.08
1.0	1.0	0	3527	4119	3823	N-33.00
1.5	1.5	0	4515	4735	4625	N144.48
handweed (3 and 6 weeks)			3748	4891	4319	N-32.10
handweed (3, 6 and 9 wks)			4523	3825	4174	N-141.15
Unweeded			3427	4244	3835	-
		LSD	± 1243	± 1243	± 879.1	
Mean			4346	4290		

Table H.III/3/1/b2. Shows maize grain yield. The effect of tillage practice on grain yield was not significant in this trial. All the herbicide treatments resulted in significant increases in grain yield over the unweeded control. Although not significantly higher, yields obtained from the plots treated with atrazine at 1 and 2 kg, atrazine/simazine 50/50 at 2 and 3 kg, atrazine/metolochlor 40/60 atrazine/metolochlor 50/50 at 2 kg and at 3 kg ai per hectare were slightly higher than those of the hand-weeded check. (Mean of both tillage practices).

With flat-planting, the following herbicides have proven promising:

atrazine at 1 kg ai/ha
atrazine/simazine at 2 kg ai/ha
atrazine/metolochlor 40/50 at 2 kg ai/ha

All these treatments have given slightly higher yield than those of the plots hand weeded three times and significantly higher yield than the unweeded check.

With ridging, none of the herbicide treatments resulted in significantly higher yield than the check but excessive hoe cultivation appeared detrimental to maize as seen on the plots weeded three times.

The most profitable application at Mokwa was 1 kg ai/ha of atrazine formulated as a 'flowable' liquid concentrate. This is currently sold at N8.70/kg ai but the cheapest formulation of atrazine as the 80% wettable powder is on sale for N5.75/kg ai and can be expected to give idemtical results when applied in very low volume. There is no reason to purchase more expensive herbicide formulations when atrazine 'w.p' can control the weed flora. It is expected that mixtures with alachlor or metolochlor will be necessary where *Cyperus esculentus* or annual sedges are present in uplant sites.

Current recommendation (Federal)

1 kg ai/ha of atrazine pre-emergence in high volume.

Proposed new interim recommendation

1 kg ai/ha of atrazine pre-emergence in very low (10 litre/ha)volume.

Experimental series. H.III/3/1c. Weed control in sorghum.

Researcher, W. B. Ndahi.

The objective of the series was to identify the optimum dosage of atrazine at Kano, Samaru and Mokwa.

The Kano trial was abandoned when sorghum failed to germinate at any atrazine dosage.

Treatments

Herbicide - Atrazine (wettable powder 80%) at 1, 2, 4 kg ai/ha.
Sites - Samaru, Mokwa and Kano.
Plot size = $\frac{ha}{454.5}$

Varieties

Samaru - Short Kaura
Kano - " "
Mokwa - Farafara

Field operation

	Kano Tractor ridge	Samaru Bmoot splitting	Mokwa Tractor ridges
Date			
Sorghum planted	10/6	26/5	10/5
Herbicide applied pre-em	14/6	30/5	13/5
Check treatments weeded	14/6	30/5	13/5
Sorghum harvested	-	3/7	28/7
	-	13/12	18/12

Table H.III/3/1ci. Effect of atrazine dosages on sorghum yield and profit at Mokwa and Samaru, 1976.

Treatment.	Dosage kg ai/ha	Samaru Sorg. grain kg/ha	Samaru Weed control profit/ha	Mokwa Sorg. grain kg/ha	Mokwa Weed control profit/ha
Atrazine	1	242.5	N42.75	1264.6	N247.17
Atrazine	2	177.7	N24.04	1326.0	N253.70
Atrazine	4	52.4	N-12.52	1368.0	N250.60
Weeded CHECK		249.3	N-24.27	1390.8	N204.03
Unweeded CHECK		168.3	-	1138.5	-
S. E.		±33.1		±119.1	

Even at Samaru where shootfly and striga attack reduced crop yield to crop failure levels the input of up to 2 units of atrazine was profitable . The increase in profitability from the second units of atrazine at Mokwa was very small and these results have to be reconciled with the results from the other sorghum experiment at Mokwa.

The failure to germinate at Kano and the higher yield at Mokwa may indicate a decrease in sorghum tolerance to atrazine from south to north. Clay contents and herbicide residues were not recorded from the actual experimental sites so that zonal dosage relationship cannot yet be developed.

Experiment H.III/3/1d. Comparison of proprietory VLV formulations for weed control in sorghum at Mokwa, 1976.

Researcher, S. Lagoke

Site: Mokwa Research Station.

A trial was conducted on general weed control in Sorghum (Tall Farafara). All herbicides were applied in very low volume (10 litres/ha) water, using the Herbispray. All the herbicides exhibited some degree of weed control in both tillage treatments.

Table H.III/3/1di. Grain yield and profitability of weed control practices in sorghum at Mokwa, 1976.

VLV herbicide dosages kg ai/ha atrazine	metolochlor	simazine	Sorghum grain yield kg/ha sown on flat	ridges	Means	Weed control profit/ha
0.5	0	0	2766			N266.45
0.5	0	0		2178		N 39.85
1.0	0	0	1376			N-15.90
1.0	0	0		2456		N 91.10
0.5	0	0			2472	N 53.15
1.0	0	0			2201	N 37.60
1.5	0	0	1732	2201	1976	N 45.25
0.25	0	0.25	2067	1312	1690	N - 7.90
0.5	0	0.5	2628	2128	2378	N - 0.30
0.75	0	0.75	2012	1884	1948	N 39.20
0.2	0.3	0	2283	1976	2130	N 81.60
0.4	0.6	0	2718	1673	2196	N 87.30
0.6	0.9	0	2891	1712	2302	N 101.00
0.25	0.25	0	2294	2136	2215	N 98.60
0.5	0.5	0	2025	2493	2259	N 99.90
0.75	0.75	0	2513	1897	2205	N 81.60
Hand weeding at 3 and 6 weeks			2812	2132	2472	N 9.24
Hand weeding at 3, 6 and 9 weeks			2494	2461	2478	N -63.69
Unweeded			1412	1957	1684	-
		LSD ±	777.85	±777.85	±550.30	
Means			2269.4	2039.9		
			LSD ± 479.74			

Table H.III/3/1di Shows that several of the herbicide treatments containi metolochlor gave high yields of sorghum. This is surprising, because metolochlor at higher dosages has killed sorghum at Samaru. On both types of seedbed the highest yield from atrazine alone was exceeded by one of the atrazine-metolochlor combinations but the profitability was of the same order.

The most profitable dosage of atrazine on the flat was 0.5 whereas on ridges it was 1.0. The difference in dosage indication as compared with the zonal series was probably due to a weaker weed challenge and higher crop population reflected in the considerably higher yield from this experiment from the unweeded CHECK treatments.

Probably the most important result of this experiment is the confirmat: that very low volume (10 litre/ha) application gave weed control which was comparable with the high volume (250 litre/ha) application used in the zonal series.

Experimental series H.III/3/1e. Weed control in cotton.

Researcher, W. B. Ndahi

The objective of the series was to identify the optimum dosage of diuron at Mkwa and Samaru.

Crop June planted cotton

Herbicide. Diuron. (80% w.p.) applied pre-emergent in high volume at 0, 1, 2 and 4 kg ai/ha on prepared ridges.

Plot size. 4 ha/454.5

Field Operation

Site	Samaru	Mokwa
Seedbed preparation	Shoot splitting	Tractor ridges
Date.		
Cotton planted	25/6	29/6
Diuron applied pre-em	29/6	30/6
Check treatments weeded	29/6	30/6
All plots weeded	30/7	28/9
Cotton picking started	14/9	17/8
	9/11	14/1

Table H.III/3/1ei: The Effect of Herbicide dosage on Seed Cotton Yields (kg/ha) In a Partially Mechanised System.

Treatments.	Samaru		Mokwa	
	Yield	Weed control profit/ha	Yield	Weed control profit/ha
Diuron 1 kg ai/ha	360.6	N58.96	352.4	N32.11
" 2 "	381.4	N60.85	515.2	N78.02
" 4 "	371.4	N48.63	317.5	N 7.61
Weeded check	471.3	N23.71	601.3	N39.70
Unweeded check	155.7	-	234.1	-

It was impracticable to prepare the site at Samaru with a tractor. This inferior seedbed preparation was the probable cause of the lower yield level at Samaru.

The Samaru site was test cropped with millet in 1977 and so far there has been no evidence of residual toxicity from the 2 kg ai/ha diuron dosage. It appears that cultivation is important for dispersing herbicide dosages because the residues from the same diuron dosage are often harmful to crops in the hoe farming experiments at Samaru.

The limited evidence from this series suggests that a higher dosage may be optimum at Mokwa than at Samaru.

Sub-project H.III/3/2. Herbicide application in partly mechanised schemes.

Researcher, W. B. Mbahi.

Many new crop production schemes do not possess tractor mounted sprayers or plentiful supplies of water for high volume spraying. Granular formulations are not readily available and are also very expensive.

This project compared locally made mixtures of herbicide with soil (herbisoil) and superphosphate (herbiliser) and 'very low volume' (VLV) application. The high volume standard was applied with conventional knapsack sprayers.

Experiment H.III/3/2a. Herbicide application to maize.

Objective

To compare various methods of atrazine application to maize with the objective of finding the best method for the partially mechanised system.

Site - Samaru (V2)

Crop - Maize 096

Herbicide - atrazine 80% w.p.

The atrazine was applied at 2 kg ai/ha to every plot.

Treatment	Description
	Pre-plant applications of atrazine at 2 kg ai/ha
1.	Herbiliser in 1st week of April.
5.	Very low volume on 'stale seedbed' early May.
	Pre-emergent applications of atrazine at 2kg ai/ha
2.	Herbiliser on split ridge pre-emergent.
3	High volume on split ridge pre-emergent.
4.	Very low volume on split ridge pre-emergent
9.	Herbisoil on split ridge pre-emergent
	Checks without herbicide.
6.	Weeded check on split ridges.
7.	Unweefed check from 1st week of April.
8.	Unweeded check from planting.

Results.

Table H.III/3/2bi. Maize grain yield kg/ha from different methods of application.

Treatment		Maize Yield	Weed control profit/ha
1.	Herbiliser ppb April	0	-
5.	VLV stale seedbed	0	-
2.	Herbiliser pre-em	500	N79.46
9.	Herbisoil pre-em.	621	N108.50
3.	High volume pre-em	1151	N235.70
4.	VLV pre-em	1333	N279.38
6.	CHECK weeded on 5/7/76	1273	N202.35
7.	Unweeded check from April.	0	-
8.	Unweeded check from planting.	121	-

No allowance was made for the costs of applying herbicides by the different techniques. High volume is certainly more expensive than herbisoil. Herbiliser and VLV are certainly the cheapest two methods but precise costs are not yet available.

The high volume method and the very low volume method, both on split ridges, gave the best results. Herbisoil also performed better than herbiliser on split ridges. The results also show very clearly that withouth seedbed preparation, soil applied herbicides cannot be used without early supplementary hoe weeding. The treatments with zero yield are treatments that did not get seedbed preparations. The fact that very low volume performed better than high volume will have a far reaching effect, since very low volume used approximately 17 litres per hectre as compared to 350 litres per hectare of water.

Experiment H.III/3/2b Comparison of methods of applying herbicides in partially mechanised cotton, Samaru

This experiment was identical in layout and execution with experiment H.III/3/2a on maize described above.

Crop. June sown cotton.

Herbicide diuron 80% wttable powder applied at 2 kg ai/ha in all herbicide treatments.

All plots were weeded once in September.

Results:

Table H.III/3/2bi Yield of seed cotton from herbicide application treatments.

Treatment	Description	Yield kg/ha	Weed control profit/ha
1.	Herbiliser ppb in April	0	-
5.	VLV on stale seedbed in May	0	-
2.	Herbiliser pre-em on split ridge	223	N 22.50
9.	Herbisoil pre-em on split ridges	239	N 27.46
3.	High volume pre-em on split ridges	527	N 16.74
4.	VLV pre-em on split ridges	602	N 39.99
6.	CHECK weeded on 8/7/76	411	N 15.77
7.	Unweeded check from April	0	-
8.	Unweeded check from aplanting	121	-

As in the maize experiment, very low volume application was more profitable than high volume whereas in spite of their very low yields the broadcast herbicide mixtures were slightly more profitable than hoe weeding.

The superior performance of VLV application compared with high volume knapsack sprayer application makes it possible to apply herbicides in crop production schemes at a labour cost of approximately N1.40/ha. The machinery cost is about 24 kobo/ha assuming that a sprayer is written-off after 50 days of operation. (This is a very pessimistic estimate). The very low volume sprayers are very simple to use but require good supervision to avoid over dosing.

It must be stressed that the results presented above were obtained with the ordinary wettable powder formulations of diuron and atrazine. The liquid 'flowable' formulations are more convenient to use but there is no evidence that they give better weed control. The cheapest available 80% w.p. formulation of atrazine costs N5.75/kg ai ex Kano, the 50% flowable from the same source costs N7.00/kg ai!

It is proposed to recommend the use of spinning disc very low volume sprayers as soon as their mechanical efficiency and reliability have been confirmed by the Agricultural Engineering Department.

Sub-project H.III/3/3 Fully mechanised weed control

Researchers: J.E.A. Ogborn and Y.M.Tanko

A fully mechanised system of weed control is one in which tractors are used for weed control operations throughout the life of the crop.

The major objective is to identify and transfer developed technology from major mechanised groundnut production areas overseas. The research component is very small because appropriate herbicides and application methods are already identified.

Experimental series. H.III/3/3a. Mechanisation of groundnut multiplication blocks.

The objective of this investigation is to reduce or eliminate hoe weeding in groundnut multiplication blocks by a combination of mechanical furrow cultivation and banded herbicide.

The objective of the 1976 trials was to select a suitable dosage of trifluralin for Kano, Samaru and Mokwa and to develop the best method of incorporation on the ridge with the Lilleston Rolling Cultivator.

It was not possible to collect quantitative weed control or yield data from the multiplication blocks but visual observations at Samaru where the trifluralin was incorporated with the small 'row-crop' rotors showed that rates of 0,4, 0.6 and 0.8 units on a 15 cm band all gave excellent early weed control and needed very little supplemental hoeing until harvest. There was practically no herbicidal weed control at Kano and Mokwa where the herbicide was incorporated with the main rotors. This was almost certainly due to the effect of the large rotors in mixing the herbicide into the whole ridge surface, giving in effect an application overall. The situation is summarised in table H.III/3/2ai.

In future observations, the herbicide will either be banded and incorporated with the row-crop rotors or alternatively incorporated overall at the appropriate dosage per total area.

Table H.III/3/3ai. Trifluralin herbicide pre-plant incorporated at Kano, Mokwa and Samaru at 0.4, 0.6 and 0.8 kg ai/ha

Centre.	Banded dosages.	Dosages total area.	Weed control.
Mokwa	.08, .12, .16	.08, .12, .16	Nil
Kano	.08, .12, .16	.08, .12, .16	Nil
Samaru	0.4, 0.6, 0.8	.08, .12, .16	All dosages effective

Project H.III/4. Control of parasitic and other noxious weeds.

This project includes all those weed problems which present special control problems outside the range of general weed control.

Sub-project H.III/4/1. Control of Striga hermonthica and related species by foliar active herbicides.

Researcher, J.E.A. Ogborn.

Experiment H.III/4/1a. Screening foliar active herbicides against Striga hermonthica in sole crop sorghum.

The final year of screening herbicides for selectivity against Striga hermonthica in sole crop sorghum had the objective of identifying the fastest acting selective formulation. The oil adjuvant 'Sun 11E' was used at the optimum concentration. The test crop was cultivar 1499 and the standard treatment for comparison was the current recommendation for crop mixtures:- [illegible] ppm + 2000 ppm oil adjuvant.

Best Available Document

Table I. Selected herbicides for sole crop sorghum.

Treatment No.	Herbicide	dosage ppm.	%oil adjuv.	killing time in weeks	grain yield t/ha	Striga kill	Striga killing dose mga/striga
Superior formulations							
11	linuron	3200	20	1.23(.004)	1.63	100	10.40
4	desmetryne	3200	20	1.29(.007)	1.49	100	6.64
5	desmetryne	6400	20	1.39(.019)	1.29	98	12.88
3	bromoxynil	12800	20	1.45(.028)	1.65	100	27.77
30	bromoxynil	3200	0	1.63(.122)	2.36(.041)	100	7.34
2	bromoxynil	6400	20	1.63(.123)	1.59	100	11.05
Formulations comparable with the oleo - ametryne recommendation							
10	linuron	1600	20	1.82	2.44(.028)	100	5.61
12	ametryne	800	20	1.96	2.75(.008)	93	2.59
1	bromoxynil	3200	20	2.18	1.78	100	17.60
oleo - ametryne recommendation (means of six)							
	ametryne	800	0.28	1.98	1.56	90	2.50

Note. The values in brackets indicate the 1-tailed significance of the differences from the means of the 'oleo-ametryne recommendation' treatment.

16 herbicides in 30 formulations were compared with the standard. 3 herbicides gave detectably faster striga control without detectable yield loss. The best ametryne formulation (treatment 12) did not kill striga faster but significantly increased grain yield. More concentrated formulations of ametryne were not selective.

Bromoxynil was selective at all dosages tested but treatment 30 formulated without oil adjuvant had a lower killing dose and a large and significant increase in grain yield. It is possible that a more concentrated formulation without adjuvant would kill faster but this result (if confirmed by larger plot tests) would be highly profitable.

Treatments 11, 4 and 5 were so active that they may be suitable for mechanised application. Treatment 4 is obviously to be preferred to treatment 5. Desmetryne at 1600 + .28% oil adjuvant was tested in 1974 and gave better control than the standard (2.2% striga maturity against 11% in the standard). The standard killing time was 3.03 weeks compared with 1.98 in 1976, nevertheless the excellent control obtained on most treatments was undoubtedly partly due to the increased adjuvant content.

Linuron has always been comparable to ametryne in its activity in screening tests but the results from treatments 11 and 10 show that it is selective at higher concentrations than ametryne and this may be a decisive advantage in sole crop sorghum. It is unlikely that the activity of linuron in treatment 11 can be improved upon by any other formulation or herbicide.

For IDFOLA application by small scale farmers, the higher selectivity of treatments 10 and 12 may be preferable in spite of the slower kill. This can only be decided by an economic study of actual farmer operations.

Formulations of cyanazine, propanil, terbuthylazine, chlorbromuron, paraquat. amitrol - T, bromphenoxime, maleic hydrazide, metoxuron, 2, 4-D, atrazine and fluorodifen were also tested but none were detectably superior to the ametryne standard.

Current recommendation (all crops and mixtures).

Ametryne at 800 ppm + 0.28% SUN 11E oil adjuvant applied with an intermittent 'Pistolgrip' sprayer.

Proposed new recommendation (sole crop sorghum only)

Linuron at 3200 ppm + 20% oil adjuvant or desmetryne at 3200 ppm + 20% oil adjuvant or bromoxynil at 3200 ppm. All these materials can be used according to local availability and price.

Experiment H.III/4/1b. Screening foliar active herbicides against *Striga hermonthica* in mixed crops.

Two potential IDFOLA herbicide formulations already proven in sole crop sorghum for their foliar activity against striga were screened in mixed crops in 1976. The screening of potential IDFOLA herbicides will be completed and reviewed at the end of the 1977 season. The results for 1976 are given in table 41b1.

Table 41b1. Activity of IDFOLA herbicides in mixed crops against *Striga hermonthica* in mixed crops, Samaru 1976

Treatment No.	herbicide	dosage ppm	% oil adj.	Survival period weeks	Striga death %	Mature striga %	Killing dose mg ai/ Striga
1	ametryne	800	.28	1.51	97.6	0	3.17
2	cyanazine	800	.28	1.37	100.0	0	2.88
3	propanil	800	.28	2.15	78.2	8.2	6.65
No IDFOLA CHECK				3.92	24.2	26.5	-

The data covers the last eight weeks of striga emergence form 11/10 onwards when striga was maturing. Damage by grazing animals affected the crop yields and delayed the statical analysis of the data. Nevertheless, the unadjusted striga data indicate that cyanazine was somewhat more active than the recommended ametryne formulation whereas propanil failed to completely prevent striga seed production. If cyanazine is found to be tolerated by crops in mixture, it will be proposed as an alternative recommended herbicide.

Current recommendation

Ametryne at 800 ppm + 0.28% SUN 11E oil adjuvant applied with on intermittent 'Pistolgrip' sprayer.

Sub-project H.III/4/2 Integrated striga control in mixed crops

Researcher, J.E.A. Ogborn.

The objective of this project is to determine the optimum combination of proven striga control techniques which can be used by small scale farmers in each ecological zone.

Possible techniques include:-

1. Intermittent directed foliar application (IDFOLA) of herbicides to kill striga.
2. Striga resistant cultivars.
3. The use of 'trap crops' (immune hosts)
4. The use of 'catch crops' (susceptible crops which are destroyed or harvested before striga can produce seed).
5. Forced germination of striga by soil application of ethylene or striga germinators.
6. Rotation of striga support crops.
7. High levels of fertiliser nitrogen.

The most effective combination will depend on the climate and farming system of each ecological zone. It has not so far been possible to make detailed observations outside Samaru.

Experiment H.III/4/2a The interaction of sorghum varietal resistance with placed fertiliser nitrogen and IDFOLA herbicides in mixed crops.

This was the first season in which a resistant striga variety was available for agronomic testing in crop mixtures.

The experiment compared the tolerant variety SK 5912 with the new resistant variety 187. These varieties are genetically related and are similar in habit of growth. Both varieties respond to high levels of placed fertiliser nitrogen when widely spaced in a crop mixture. They were sown as a square matrix at 4306 stands/ha in mixed crops.

A comparison of nitrogen levels was imposed factorially on the whole experiment. Table H.III/4/1ai shows the effect of these two factors in the absence of IDFOLA herbicide control. The total striga emergence was very low during this season because of the prolonged humid period.

The first mature striga plant was observed on 11/10/76 and the emergence data is therefore divided into two periods.

The resistant variety consistently supported a lower striga emergence in both periods. High fertiliser nitrogen reduced striga emergence on the short Kaura by 37% (P = .054) and 33% (P = .040) in the earlier and later periods respectively. Nirogen levels did not affect early emergence on variety 187 but did reduce the later emergence by 48% (non-significant).

Table 42a1. Effect of varietal resistance and placed fertiliser nitrogen on striga emergence and yield of sorghum in a crop mixture

Variety	SK	SK	187	187
Placed N kg/ha	25	125	25	125
Striga emergence 1000s/ha 23/8 - 4/10	4.40	2.76	0.99	0.99
S.E.		±.501		
Mature striga	2,94	1.00	0.43	0.29
Grain yield kg/ha	158	89	204	326
S.E.		± 42.9		

Varietal resistance and high nitrogen both reduced striga seed production but it must be emphasised that even 290 striga/ha are quite enough to maintain a damaging infestation. They contain approximately 72 million seed!

Variety 187 cannot therefore be used to eradicate striga without vigorous phyto-sanitation to prevent any seed being ripened. The main advantage of this variety is that the supplementary control effort needed is so small. (10% of that required for the SK 25 treatment).

Variety 187 also gave a profitable response to high nitrogen whereas Short Kaura yields were depressed. The exact reasons for this are not yet clear but the result emphasises the merit of variety 187 as a component of crop mixtures.

The effect of additional fertiliser nitrogen was broadly similar in its effects to genetical resistance. Neither technique eliminated striga seed production when IDFOLA was not used but both reduced the amount of IDFOLA applied to eliminate striga seed production. The indications from this first season therefore are that resistant varieties should be used when available but that additional N is an effective way of reducing emergence in tolerant varieties to levels which can be controlled by IDFOLA.

Experimental series H_III/4/2b. Rotation of striga support crops by mixed cropping without sorghum (LCWS).

This technique of striga control was conceived when it was observed that at Samaru, sorghum was the only susceptible crop to support the production of Striga hermonthica seed. The other susceptible crops millet, maize and upland rice all being harvested earlier than the normal date of striga seed production in mixed crops.

Table 1. Dates of striga seed production and crop harvests.

	1975	1976
Millet harvest	4/9	25/8
Maize harvest	9/10	7/10
Rice harvest	9/10	12/10
Striga seed 1st ripened	11/10	18/10
Sorghum harvest	11/12	27/12

This implies that any striga parasitising these three crops is automatically killed when the host becomes senescent at harvest.

Most of the other crops growing in the traditional hoe farmers crop mixtures (groundnuts, cowpeas, yams etc) have been reported to be 'immune hosts' of S. hermonthica, that is, they produce root exudates which germinate the striga seed but are not parasitised themselves.

The traditional crop mixture without sorghum therefore combines the two proven methods of cultural control which were successfully used in large scale farms in Africa before the introduction of herbicides. These were 'catch-cropping' with susceptible host crops and 'trap-cropping' with immune host crops.

Norman (1972) found that 22% of the total cropped area near Zaria was sorghum while 6% was grown as sole crop sorghum.

If all the sorghum were to be grown as sole crop and rotated round the total cropped area, there would be an approximate five phase rotation. Four phases of mixed cropping would actively reduce the striga seed population in the soil while only one phase (sole crop sorghum) would be able to support striga seed production. Striga control in sole crop sorghum is much easier than in mixture and need be applied in only one fifth of the total cropped area.

A pilot scale observation on 8 acres of farmers land at Doka village was started in 1975. Two farmers undertook to grow all their sorghum in sole crop. Six acres of mixed crops without sorghum and two acres of sole crop sorghum were grown. The sole crop sorghum received one cwt of 20 - 10 - 10 fertiliser per acre of mixed crops. The resulting rates of fertiliser nitrogen 101 and 50 kg/ha respectively produced very vigorous growth of sorghum which virtually confined the effective emergence of the striga to the crop margins. No striga at all emerged in the six acres of mixed crops.

Shortage of staff prevented the recording of crop yields or the counting of the striga emerging in the sole crop sorghum. Shortage of staff prevented the continuation of the project in 1976.

Best Available Document

This one year observation on farmers land confirmed that striga did not produce seed in the absence of sorghum and that striga emergence was much reduced in the sole crop sorghum. Striga emergence in the normal mixed crops adjacent to the trial area was conspicuous and plentiful.

A small plot observation was also started at Samaru to obtain some accurate quantitative information about the effect of mixed cropping without sorghum on susceptible crop yields. A set of five spare plots adjacent to the 'Striga control in mixed crops experiment' was laid down to a formal five year rotation with one plot of sole crop sorghum being grown each year. The adjacent 'no striga control' check plots in the mixed crops experiment were used for comparison. The effects on striga emergence are presented in Table 2.

Table 2. Effects of rotation of sorghum as a sole crop on emergence and maturation of striga in mixed crops at Samaru 1975 - 76

	Striga eradication rotation		Traditional cereal mixtu	
	Sole crop sorghum SK 5912	no sorghum	tolerant sorghum SK 5912	resistan sorghum 187
Striga emergence ha. 1975 season (1000s/ha)				
Per cropped ha.	12.70	.09	6.62	-
Per rotation ha.	2.63		6.62	-
Mature striga	1.72		2.30	-
Striga emergence ha 1976 season (1000s/ha)				
Per cropped ha.	1.51	0	10.12	6.03
per rotation ha.	0.30		10.12	6.03
Mature striga	0.13		2.94	0.43
Kg.N/ha of sorg.	31.2	-	6.2	6.2
Kg.N/ha of rotation	6.2		6.2	6.2

The replication of the observation is too limited for precise statistical analysis and rotation effects are confounded with seasonal variation but the changes observed appear to be too large to be due to chance. In both seasons the total striga emergence was less on the eradication rotation plots, while in 1976, emergence decreased by 89% on these plots and actually increased by an average of 22% (in spite of the introduction of a resistant sorghum) on the sorghum mixture plots.

In 1976, the resistant variety, reduced emergence by 40% while 1 year of mixed cropping without sorghum reduced emergence in the tolerar variety by 97%! It would appear that MCWS is a potent means of reducing striga infestation.

This is confirmed by an examination of the susceptible crop grain yields. The effect of sole cropping on sorghum is mostly a direct effect of improved competition for light. The effects on grain yield are presented in Table 3.

Table 3. Grain yields of sole crop versus mixed crop sorghum in the presence of striga 1975 - 6. (kg/ha)

	Striga eradication rotation, sole crop SK 5912	Traditional cereal mixture tolerant SK 5912	resistant 187
Sorghum yields. 1975			
Per cropped ha.	670	103	-
Per rotation ha.	134	103	-
Sorghum yields. 1976			
Per cropped ha	1561	114	126
Per rotation ha.	312	114	126

In both seasonsthe single sole cropped plot out-yielded the total of five plots of sorghum mixture.

The effects on the millet, maize and upland rice can be stributed to changes in the striga infestation caused by mixed cropping and the removal of competition from the sorghum. The yields obtained after one season of MCWS are presented in Table 4264.

Table 4264: Yields of striga susceptible cereal grain (kg/ha) in 1976 after 1 season of MCWS in 1975.

	Striga eradication rotation[1]			Sorghum mixture
	After sole sorghum	After MCWS	Mean	
Maize yields per cropped ha.				
	882	844(.000)[2]	854(.000)	533
Upland rice yields per cropped ha.				
	654	1225(.026)	1082(.029)	452
Millet yields per cropped ha.				
	1632	940(.155)	1113(.192)	1774

Notes 1. All yields in this rotation are adjusted for the smaller proportion of mixed crops in this rotation by multiplying by 0.8.

2. Values in brackets indicate the exact statistical significance of the difference from the sorghum mixture yields.

The effect was to increase maize yields highly significantly by 60%, to increase rice yields significatly by 139% while millet yields dropped non-significantly by 37%.

This result confirms previous observations that maize can be severely damaged by striga at Samaru while millet is apparently not attacked at all. The size of the response in upland rice is surprising because rice has never before been observed to be damaged at Samaru. Part of the effect may be due to the removal of competition from the sorghum.

The potential value of this technique of striga eradication cannot be doubted because it involves the minimum of changes in the traditional mixed cropping practices and involves no additional inputs.

The area where it can be successfully practiced, depends on the extent of the area where sorghum is the only striga support crop. Millet, maize and rice have all been observed to support striga seed production in the Sudan zone while there are reports that maize and upland rice may do so in seasons of bimodal rainfall in the southern Guinea zone.

Reference. Norman, D.W. (1972) Samaru Misc. Paper, 37.

Sub-project H.III/4/3 Eradication of Imperata cylindrica with herbicides

Researcher, S. Lagoke.

Experimental series H.III/4/3a Chemical Control of imperata in the wet season

Most herbicides like asulam and glyphosate were less effective on imperata in the wet season than in the dry season. Dalapon was quite effective in the wet season. Tetrapion did not seem to have potential for imperata control when investigated in the wet season.

IMPERATA CONTROL WITH DALAPON

Site: Erinle.

This trial was conducted in the wet season. Dalapon treatments were either applied once, split, followed by paraquat application, or with additional wetter (Ref. Table 43a). Second applications were done at two weeks later. All sprayings were done in 300 litres of water per hectare.

Results show the degree of imperata control based on visual scores at 20 weeks after the first application. All the herbicide treatments effectively reduced the imperata regrowth score, giving between 72 and 97% imperata control. Single application of dalapon at 10 and 15 kg ai/ha caused less imperata control than dalapon at 7.5 kg ae, probably because of immobilization due to necrosis caused by the high concentration of solution. However, split-application of these rates of dalapon considerably improved their activity on imperata by 7% and 15% respectively. There was no advantage in split-applying the highest rate of dalapon. When split-applied, 10 kg ai/ha dalapon (5 + 5) was as effective as a single application (of 20 kgai/ha dalapon). Additional wetter enhanced the activities of higher rates of dalapon i.e. (7.5, 10 and 15) considerably. This enhancement increased with rates. Follow-up application of paraquat did not increase the activities of 5 and 7.5 kg ai/ha dalapon.

Further investigation to confirm the effective rates on different stages of imperata will be carried out in 1977.

Table 43a. The use of dalapon to control imperata in the wet season, Site: Erinle

Herbicide dosage kg ai/ha		% Control
Dalapon at 5.0	+ 0.2% Wetter	78
Dalapon at 7.5	+ 0.2% Wetter	94
Dalapon at 10.0	+ 0.2% Wetter	90
Dalapon at 15.0	+ 0.2% Wetter	80
Dalapon at 20.0	+ 0.2% Wetter	94
Dalapon at [a]5+5	+ 0.2% Wetter	97
Dalapon at [a]7.5+7.5	+ 0.2% Wetter	95
Dalapon at [a]10+10	+ 0.2% Wetter	96
Dalapon at 5+0.2% Wetter	+ paraquat at 0.5	80
Dalapon at 7.5+0.2% Wetter	+ paraquat at 0.5	72
Dalapon at 5	+ 0.4% Wetter	85
Dalapon at 7.5	+ 0.4% Wetter	88
Dalapon at 10	+ 0.4% Wetter	83
Dalapon at 15	+ 0.4% Wetter	53
CHECK (no herbicide)		0

a. Split application.

Chemical Control of Imperata with tetrapion

Tetrapion was applied at the rates of 4 and 6 kg ai/ha in very low volume (20 litres of water) or solubilized and applied in oil, while 4, 6 and 8 kg ai were applied in 300 litres of water per hectare. Application was made on dense imperata cover. Even at 9 weeks after application only tetrapion at 8 kg ai per hectare affected about 6% scorching. While none of the other treatments caused more than 20% scorching. Within 11 weeks after application vigorous regrowth had started on the plots treated with 8 kg ai/ha.

Further work on the use of tetrapion will be discontinued since it does not appear potent for imperata control.

Experimental series H.III/4/3b. Chemical control of Imperata-dry season

Imperata control with asulam

Site: Mokwa Research Station.

As a preliminary investigation, asulam was applied in two different volumes (300(HV) and 10(VLV) litre/ha at rates 4 to 8 kg ai/ha with or without additional wetter or in solution of pH 9.2 or ammonium sulphate. Application was done on January 28th, 1976. Results on shoot weight of imperata at 17 weeks after spraying are shown in table 43b1.

The activity of asulam at 6 kg ai/ha in VLV was enhanced by additional wetter (0.2%) to cause a reduction in the means of all main treatments. This enhancement mainly occurred on the plots slashed at 3 weeks and those not slashed after spraying. Slight improvement was also caused by additional wetter on the plots slashed at 2 weeks after spraying. The activity of 4 kg ai/ha asulam was also slightly improved by this additional wetter in all the main treatments.

Solubilization also improved the efficiency of asulam against imperata. This was most obvious on the plots slashed at 2 weeks after spraying where rapid absorption was a major factor in determining the final effect of the chemical. Solubilized asulam was even more effective than VLV aqueous asulam plus additional wetter on the plots slashed at 2 weeks after spraying. There was no advantage in applying a higher rate (8kg) of asulam in this experiment. This investigation still continues.

Table 43b1. Effect of different volumes of application and additives on the activity of asulam on imperata

Imperata dry matter production at 17 weeks after spraying, kg/ha.

POST - SPRAYING SLASHING AT

	2 weeks		3 weeks		unslashed		mean	
	wt	sig.	wt	sig.	wt	sig.	wt	sig.
8 kg ai/ha HV aqueous	759		1026		741	.114	836	
6 kg ai/ha HV aqueous	466	.054	664	.154	456	.018	521	
6 kg ai VLV aqueous	740		1155		997		949	
4 kg ai VLV aqueous	637	.158	846	[illegible]	686	.074	707	.083
6 kg ai VLV aqueous Ph 9.2	505	.072	658	.150	634	0.86	611	0.38
4 kg ai VLV aqueous Ph 9.2	809		334	.012	1020		658	.057
6 kg ai VLV Oileou.	168	.001	334	.012	823	.160	366	.002
4 kg ai VLV Oil	596	.127	795		534	.051	656	.056
6 kg ai + 0.2% CIBA Wetter VLV aqueous	345	.017	191	.001	238	.001	251	.000
4 kg ai + 0.2% CIBA Wetter VLV aqueous	856		179	.001	618	.059	466	.003
6 kg ai + 0.2% CIBA Wetter HV aqueous	1303		1289		1259		1283	
6 kg ai + $(NH_4)_2 SO_4$ at 10kg/ha HV	486	.062	473	.047	619	.060	522	.016
15 kg ai/ha HV	204	.002	355	.0157	253	.002	264	.000
CHECK	1016		1065		1299		1120	
MEAN	563		570		663			

The statistical (1-tailed) significance of the differences between the formulation means and the CHECK is shown where appropriate.

Effect of Solvents, Volumes of application and additives on the activity of asulam of imperata

Asulam was applied in water at high volume (300 litre/ha) and very low volume (10 litre/ha) of water with different extra additives, and also solubilized using either glycerine or glycerol monoleate and applied in either very low volume diesel or sun 11E oil (Table 43b2).

At four weeks after application with extra additives 2% and 4%, high volume application effected better scorching of imperata foliage than VLV application. This was most pronounced with the use of Adhesol at 4% of the spray solution. Agrol VLV applied with 4% additive was more effective than 2% additive. Solubilized asulam VLV was only comparable to the former when glycerine was used as the solubilizer irrespective of the oil used. The use of glycerol monoleate resulted in lower activity. At 9 weeks after spraying, imperata green regrowth score did not deviate much from the observed scorching effect of the treatment on imperata. Results on the effects of these treatments on imperata dry matter production are still being compiled.

Table 43b2. Effect of volumes, solvents of application and additives on the activity of asulam on imperata

	Scorching %	%Control of Regrowth
Asulam + 2% Agral HV (aqueous)	100	100
Asulam + 2% Agral VLV (aqueous)	60	73
Asulam 6 kg + 4% Agral HV (aqueous)	100	97
Asulam 6 kg + 4% Agral VLV (aqueous)	80	80
Asulam 6 kg 2% Adhesol HV (aqueous)	100	100
Asulam 6 kg 2% Adhesol VLV (aqueous)	70	83
Asulam 6 kg 4% Adhesol VLV (aqueous)	95	97
Asulam 6 kg 4% Adhesol VLV (aqueous)	70	73
Asulam 6 kg solubilized (a)(diesel) VLV	60	83
Asulam 6 kg solubilized (b)(diesel) VLV	85	93
Asulam 6 kg solubilized (a)(Sun 11E)VLV	65	70
Asulam 6 kg solubilized (b)(Sun 11E)VLV	80	93
Asulam 6 kg in Diesel VLV	55	60
Asulam 6 kg in Sun 11E VLV	75	80
Asulam 8 kg in water HV	70	73
CHECK (unsprayed)	0	0

Experimental series H.III/4/30. Chemical control of imperata with glyphosate

Site: Mokwa Research Station.

This trial was started on 8th February, 1976 and terminated on 8th June, 1976. Glyphosate at rates 0.5 and 0.75 per hectare were either applied in 300 or 10 litres of water per hectare with or without additional wetter, in solutions of ammonium sulphate Ph 9.2; Glyphosate was also applied at 1 kg ai/ha in 300 L per hectare, for comparison.

Table 43c1. Effect of different volumes of application of glyphosate on imperata dry matter production at 17 weeks spraying (kg/ha)

	POST-SPRAYING CUTTING AT							
	3 days after spraying		1 week after spraying		unslashed		mean	
	weight	sig.	weight	sig.	weight	sig.	weight	sig.
Glyphosate 1 kg HV	1245	.009	742	.013	796	.001	903	.000
Glyphosate 0.75 kg HV	1485	.010	1143	.065	1229	.008	1278	.001
Glyphosate 0.5 kg HV	1472	.019	1086	.054	2691	.152	1629	.007
Glyphosate 0.75 kg in pH 9.2 HV	1633	.029	1150	.066	2243	.085	1617	.007
Glyphosate 0.5 kg in pH 9.2 HV	2535	.135	1501	-	1865	.044	2081	.037
Glyphosate 0.75 kg + $(NH_4)_2SO_4$ HV	1216	.009	1011	.042	1549	.021	1240	.001
Glyphosate 0.5 kg + " " "	647	.001	747	.013	2238	.084	1109	.000
Glyphosate 0.75 kg + 0.2% wetter HV	936	.005	1055	.049	1182	.007	1053	.000
Glyphosate 0.5 kg + " " "	1552	.023	870	.024	2217	.081	1441	.003
Glyphosate 0.75 kg VLV	1004	.004	281	.000	1071	.005	679	.000
Glyphosate 0.5 kg VLV	1601	.026	621	.006	2215	.081	1307	.002
Glyphosate 0.75 kg in pH 9.2 VLV	458	.000	335	.000	775	.001	494	.000
Glyphosate 0.5 kg in pH 9.2 VLV	1580	.025	975	.037	1163	.007	1215	.001
Glyphosate 0.75 kg + $(NH_4)_2SO_4$ VLV	1189	.020	343	.001	639	.001	696	.000
Glyphosate 0.5 kg + " " "	529	.000	519	.003	1460	.017	741	.000
Glyphosate 0.75 + 0.2% wetter VLV	534	.000	266	.000	234	.000	323	.000
Glyphosate 0.5 + " " "	320	.000	232	.000	365	.000	321	.000
CHECK (no herbicide)	4420	-	2497	-	4504	-	3678	-
Means (all herbicide formulations)	1049	.191	676	.001	1192	-		

The statistical (1-tailed significance of the differences between treatment means and their CHECKs is shown where appropriate.)

Table 43c1 contains data on imperata dry matter production 17 weeks later. Imperata dry matter production was affected by the time of post spraying shoot removal but excellent imperata control was obtained with the best VLV formulations even without slashing. Very low volume (10 litre/ha) application enhanced the activity of glyphosphate especially when additional wetter (a total of 0.4%) was used with the 0.5 and 0.75 kg ai/ha glyphosate dosage.

These treatments caused lower imperata dry matter production than glyphosate at 1 kg ai per hectare applied in 300 litres of water. Slight enhancement of the activity of 0.75 kg ai/ha glyphosate in 10 litre/ha wa observed when applied in pH 9.2.

Effect of formulation, volume of application and additives on the activity of glyphosate on imperata (Table 43c2) early wet season.

The enhanced effect of VLV application on the activity of 0.75 kg ai/ha glyphosate observed in the dry season preliminary trial was not replicated in this trial. Solubilization extra wetter or ammonium did not enhance the activity of any of the three rates used. It was observed that 1 kg ai/ha glyphosate could not be successfully applied in VLV, even with extra wetter. The application of this rate in 300 litres of water per hectare, was as effective at 4 kg ai/ha. Within 7 weeks of application, the maximum control observed in this trial had declined to 45%.

Table 43c2. Effect of Formulation, Volume of application and additives on the activity of glyphosate on imperata.

		Scorching % At 5 weeks A.S.	% Control of Green regrowth (9 weeks)
Solubilized glyphosate	b0.5 cVLV	50.0	25
Solubilized glyphosate	0.75 VLV	67.5	40
Solubilized glyphosate	1.0 cVLV	65.0	30
Glyphosate aqueous	0.5 VLV	70.0	25
Glyphosate aqueous	0.75 VLV	75.0	35
Glyphosate aqueous	1.0 VLV	75.0	45
Glyphosate + 2% Agral	0.5 VLV	70.0	45
Glyphosate + 2% Agral	0.75 VLV	77.5	30
Glyphosate + 2% "	1.0 VLV	75.0	40
Glyphosate + $(NH)_2SO_4$	0.5 VLV	57.5	35
" "	0.75 VLV	67.5	40
" "	1.0 VLV	60.0	30
Glyphosate (aqueous)	0.5dHV	65.0	35
" "	0.75 HV	60.0	40
" "	1.0 HV	92.5	30
" "	2.0 HV	90.0	15
" "	4.0 HV	92.5	45

a = Commercial solubilized glyphosate

b = Kg ai/ha

c = Very low volume (20L/ha)

d = High volume (300 L/ha)

A.S. = After spraying

Sub-project H.III/4/4 Eradication of Imperata cylindrica by cultivatio

Experiment H.III/4/4a Effect of cultivation on imperat with standard tractor equipment.

This trial was conducted at Mokwa Research Station. The first prim cultivation using disc plough and chisel phough on two different strips were done on 12/1/76, while the second primary cultivations were done on 28/5/76. It was only possible to use the disc and chisel ploughs in the first dry season cultivation because the soil was too hard to allow for the penetration of other implements and there were no new spare rotavator blades. An effective one furrow disc plough was obtai by removing the two rear discs from a standard 3 furrow machine. This modification was essential to obtain the necessary 25 cm (10") plough depths.

The treatments were self-defining in that the secondary cultivations were applied as necessary - at 50% imperata shoot regrowth.

The results on imperata regrowth and cultivation requirements are shown in table 44a.

Table 44a. Cultivation requirements for imperata control.

Treatment.	Supplementary cultivation dates	Imperata dry matter kg/ha 12/1/77 weed wt.	sig.
Dry season primary cultivation on 12/1/76			
Disc plough	None	491	.000
Chisel plough	28/5/76, 4/8/76	893	.013
Early wet season primary cultivation on 28/5/76			
Disc plough	31/8/76	570	.001
Chisel plough	4/8/76	439	.000
Rotavator	[illegible]	218	.000
Underbuster	27/19/76	278	.000
No cultivation			
CHECK	-	1858	-

The statistical (1-tailed) significance of the differences between the cultivation mean weed weights and the 'no-cultivation' CHECK is shown under the column 'sig.'.

The best imperata suppression was obtaine with dry season disc ploughing where only 26% regrowth occurred during the following season. In the early wet season, these plots were infested with Cleome viscosa which was succeeded by Pennisetum pedicellatum at the end of the rains.

Disc ploughing was less successful in the wet season and needed to be disc harrowed before the end of the rains.

Chisel ploughing was less effective in both seasons, probably because the model used (an MF 25) could not penetrate effectively to the required depth under the conditions of the trial.

The results of this first effective cultivation experiment confirm previous observations by Ogborn and Lashilola at Zuru and Mokwa that a single dry season ploughing will eradicate vegetative imperata. The appearance of an annual weed cover confirms that the imperata was actually eradicated. The regrowth which eventually occurred was almost certainly a reinvasion of seedling imperat. This reinvasion is easily controlled by normal general weed control during cropping.

Current Recommendation

None.

Proposed Recommendations.

1. Derived forest savanna zone

Dalapon herbicide at 10 kg ai/ha in 300 litre/ha applied in April or at 60 cm new imperata growth (whichever is earliest) six weeks before cropping with cereals.

2. Southern guinea savanna zone

0.75 - 1.0 kg ai/ha of glyphosate applied in 20 litre/ha in January after burning prior to normal wet season cropping. (suitable for small infested areas).

3. Southern guinea savanna and derived forest savanna.

Cultivation with a disc plough to a depth of 25 cm before February prior to normal wet season cropping.

Recommendations 2 and 3 may be combined if desired.

Project H.III/5. Weed Control in Irrigated Areas.

Sub-Project. Selective weed control in crops.

Objectives - To identify suitable herbicide(s) and dosages for selective weed control in crops grown in irrigated areas, in both the wet and dry seasons.

Starting Date 1973

Researcher(s) A.H. Choudhary

Progress Report (1976 - 77 results)*

H.III/5/1a. Effect of herbicides on the control of weeds in maize (wet season)

Alachlor plus atrazine, butylate plus atrazine and atrazine alone were tested at different rates at Samaru, Kadawa and Dep. The results are given in table 51a1.

Samaru site was infested with Cyperus rotundus apart from annual grasses and sedges. There were few broad leaved weeds. Here butylate plus atrazine at 4.5 + 1.5 or 6 + 2 kg/ha and alachlor plus atrazine at 3 + 1.5 kg/ha proved better treatments causing a significant reduction in the growth of C. rotundus as well as other weeds with a consequent increase in the total dry matter and grain yield of maize. Butylate plus atrazine at 3 + 1 kg/ha gave a slightly inferior weed control while alachlor plus atrazine at 2 + 1 kg/ha as well as both rates of atrazine were not effective on C. rotundus.

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* All rates of herbicides are in kg (active) per hectare.

Terminology Used:

Pre-em: (Pre-emergence) After sowing but before crop emergence.

Post-em: (Post-emergence) After crop emergence.

PPI: (Pre-plant incorporated) Before sowing and incorporating in the soil.

PPWF: (pre-plant on weed foliage) On the foliage of weeds before sowing the crop.

Table Six. Effect of Herbicides on Weed Weights/Cover, Maize Grain and Total Dry Matter (kg/ha)[1]

Treatment	Samaru				Kadawa			Dep.	
	Cyperus spp.[2] kg/ha	Total Weeds[2] kg/ha	Maize Grain	Maize TDM	Weed[3] Cover	Maize Grain	Maize TDM	Weed[3] Cover	Maize Grain
1. Alachlor at 2 + atrazine at 1 pre-em	1531 bc	1632 cd	5046 a	9672 ab	0.88 a	6799 a	14796 a	2.0 b	3310
2. Alachlor at 3 + atrazine at 1.5 pre-em	698 a	705 a	5154 a	10459 a	0.75 a	6625 a	13701 ab	2.3 b	3858
3. Butylate at 3 + atrazine at 1 ppi	1053 ab	1319 bc	5046 a	9356 ab	3.12 c	6306 abc	13294 abc	6.5 cd	2840
4. Butylate at 4.5 + atrazine at 1.5 ppi	844 ab	868 ab	5509 a	10814 a	0.88 a	6634 a	14417 ab	6.0 cd	2731
5. Butylate at 6 + atrazine at 2 ppi	566 a	500 a	5278 a	11007 a	0.62 a	6505 ab	13153 abc	4.5 c	3458
6. Atrazine at 1 pre-em	2427 c	2627 de	3991 b	7473 b	4.62 d	5271 c	11315 c	5.2 c	3356
7. Atrazine at 2 pre-em	1518 bc	1663 cd	4769 ab	8927 ab	1.62 b	7151 a	14935 a	2.7 b	3660
8. Hoe weeded (twice)	-	-	4568 ab	9398 ab	-	5454 bc	12394 bc	0.7 a	3319
9. Unweeded	847 a	4337 e	1466 c	5272 c	8.88 e	2712 d	6421 d	7.7 d	2546
S.E.	tr	tr	509	817	tr	365	631	tr	352

1. Data in the same column followed by a common letter are not significantly different at the 5% level by using Duncan's Multiple Range Test.

2. Weed weights at the time of tasseling of maize (oven dry basis). Data transformed to logarithm $x = \log_{10} x$ for analysis.

3. Visual rating on a scale of 0 - 9, where 0 = no weeds; 9 = full of weeds. The analysis done on the data transformed to square root $x = \sqrt{x + 0.5}$.

KADAWA had a different weed-spectrum. Here annual broad leaved weeds and grasses were the main problem and 2 kg/ha of atrazine gave the highest yield although the weed control was not as spectacular as that given by both rates of alachlor combination and two higher rates of butylate combination with atrazine. There was no significant difference, however, in grain and TDM of maize in the above mentioned treatments. Lower rate of butylate - atrazine mixture was again slightly inferior while atrazine at 1 kg/ha was definitely poor.

IKP site was dominated with broad leaved weeds. Here butylate combinations did not look as effective on weeds as atrazine at 2 kg/ha or alachlor combinations. At this site incorporation of butylate + atrazine was done with a tractor drawn disc harrow and, therefore, the incorporation was deeper than Samaru and Kadawa where it was done with hand hoe. Thus atrazine got diluted and was not very effective. Herbicides giving better weed control gave maize grain yield comparable to that from hoe weeded treatment and better than unweeded.

At another location in Kadawa different combinations of same herbicides were tested on a site infested with Cyperus esculentus and annual weeds. The results, given in table 51a2, confirm that alachlor and butylate are weak on broad leaved weeds and their mixture with atrazine gives a better weed control. It was also observed that post-emergence application of atrazine at 2 kg/ha with Sun Oil 11E alone or following a pre-emergence application of atrazine at the same rate can give effective C. esculentus control. Otherwise there does not seem to be much advantage in the post-emergence application of atrazine with oil over that of pre-emergence atrazine on the overall weed control.

Table 51a2. Effect of Herbicides on Cyperus esculentus, Annual Grasses and Broad Leaved Weeds and Maize Grain (kg/ha)

Treatment[1]	C. esculentus[2]	Grasses	Broad Lvd	Total Weeds	Maize Grain
1. Atrazine 2 pre-em	544	1569	0	2113	6474
2. Atrazine 2 post-em	124	1181	396	1701	5353
3. Atrazine 2 + 2 post-em	12	849	0	861	5042
4. Alachlor 3 pre-em.	70	605	1019	1694	5385
5. Alachlor 2 + atrazine 1 pre-em	111	1511	11	1633	5571
6. Alachlor 3 + atrazine 1.5 pre-em	61	350	7	418	5634
7. Alachlor 2 pre-em + atrazine 1 post-em	15	1856	0	1871	7096
8. Alachlor 3 pre-em + atrazine 1.5 post-em	83	1050	0	1133	5291
9. Butylate 4 ppi	74	649	1893	2616	6225
10. Butylate 6 ppi	6	247	951	1204	5385
11. Butylate 3 + atrazine 1 ppi	31	839	89	959	5322
12. Butylate 4 + " 2 ppi	67	573	6	646	5447
13. Butylate 3 ppi + " 1 post-em	12	879	6	897	6318
14. Butylate 4 ppi + " 2 "	8	81	0	89	5540
15. Hoe weeded (twice)	-	-	-	-	5385
16. Unweeded	419	3153	121	3693	3922

1. Post-emergence atrazine applied with Sun Oil 11E at 10 litre/ha.

2. Weed samples taken at the time of tasseling of maize.

Study of the residual effects of herbicides applied during the rains.

The experimental plots were cultivated and test cropped with tomatoes cv Roma VFN at Samaru and Kadawa. The marketable tomato yields are given in table 51a3. A slight depression in yield was observed with 2 kg/ha of atrazine alone or in combination with 6 kg/ha of butylate at Samaru, although this was not significant. No such trend was observed at Kadawa where the soil is lighter and the herbicides leach down quickly.

Table 51a3. Residual Effects of Herbicides Applied in Maize on the Following Crop of Tomatoes

Treatment	Marketable Tomatoes (Tons/ha)	
	Samaru	Kadawa
1. Alachlor 2 + atrazine 1	45.9	38.3
2. Alachlor 3 + atrazine 1.5	47.2	41.6
3. Butylate 3 + atrazine 1	48.9	38.0
4. Butylate 4.5 + " 1.5	48.7	42.0
5. " 6.0 + " 2	42.2	41.6
6. Atrazine 1	49.0	38.7
7. Atrazine 2	43.3	38.2
8. Hoe weeded (twice)	50.5	41.5
9. Unweeded	41.4	42.5
S.E.	3.4	2.4

Current recommendation

Nil

Proposed interim recommendation

- Use atrazine at the rate of 2 kg ai/ha pre-emergence on medium textured soils infested with annual broadleaved and grass weeds.
- Alachlor plus atrazine may be used at the rates of 2 + 1 kg ai/ha, respectively, pre-emergence on medium textured soils dominated with Cyperus esculentus and/or annual grasses and sedges with broadleaved weeds.
- Butylate plus atrazine should be used at the rates of 4.5 + 1.5 kg ai/ha, respectively, as pre-plant incorporated treatment on medium textured soils when the site has an ifestation of Cyperus rotundus or Cyperus tuberosus in addition to those mentioned for alachlor combination.
- When the site is heavily infested with perennial Cyperus spp. herbicidal application should be preceded by thorough seedbed preparation.

H.III/5/1b. Effect of herbicides on the control of weeds in groundnuts

Vernolate, alachlor, trifluralin alone and trifluralin followed with post-emergence Cyperquat were compared with two hoe weedings in a field trial at Kadawa in groundnut CV S38. The site was infested with annual broad leaved weeds grasses and sedges with very little C. tuberosus present.

Alachlor at 3 kg/ha looked better amongst the herbicidal treatments. It kept the plots clean in the early part of crop growth and the yield was comparable with two hoe weedings (table 51b). The effect was short lived, however, and the plots started to become weedy 4-5 weeks after herbicidal application. The effect of its lower rate was very short lived while the highest rate of 4.5 kg/ha caused stunting of groundnuts although it kept the plots clean for a longer time.

Vernolate was not impressive while trifluralin was in effective. Very soon the plots became dominated with annual sedges in the trifluralin treatment which were than overtaken with broad leaved weeds. Cyanazine applied post-emergence after trifluralin killed the sedges but was not effective on other weeds.

Generally the groundnut yield was very poor. This could be partly due to late planting and also due to the fact that the entire experimental area became dominated by broad leaved weeds especially Acanthospermum hispidum which smothered the groundnut crop. It appears that the herbicidal effect was reduced quickly as a result of leaching in the lighter soils of Kadawa before the crop closed its canopy. Also the herbicides used in this experiment are rather weak on broad leaved weeds. A light hoe weeding before pegging may be necessary in most situations to remove late emerging broad leaved weeds.

Current recommendation

Nil

Proposed interim recommendation

Use alachlor at 3.0 kg ai/ha as pre-emergence application on medium textured soils dominated with Cyperus esculentus and annual grasses.

H.III/5/1c. Testing of herbicides for weed control in cotton

Perfluidone, norflurazone alone and followed with post-emergence MSMA, and diuron followed with MSMA were compared at Ngala, Kadawa and Samaru. The Ngala trial had to be written off as a result of weeding of experimental plots by mistake while the results from Samaru and Kadawa are given in table 51c1. The weed flora consisted of C. rotundus, annual grasses and broad leaved weeds at Samaru and broad leaved weeds, annual grasses with little C. tuberosus at Kadawa. Unweeded plots were also included as one of the treatments, although left out in the statistical analysis, to see the potential growth of the weeds and compare with herbicidal treatments. They were also useful to see the extent of damage caused by leaving the weeds uncontrolled.

Perfluidone at 4 kg/ha proved to be the best herbicide at both locations. It gave good control of all the weeds and best seed cotton yield. Its lower rate ie 2 kg/ha was inferior to it in all respects. It appears that 3-4 kg/ha should be optimum depending upon the soil type. In fact 3 kg/ha of perfluidone kept cotton plots weed free and seed cotton yields were comparable to two hoe weedings on another part of the same field at Samaru. The dominat weeds were C. rotundus and C. esculentus.

Norflurazone was not as effective as in the previous year at both sites. It lost its effectiveness very quickly in a wet year. Weed control and seed-cotton yield were slightly better at 2 kg/ha than at 1 kg/ha. When followed with MSMA at 2 kg/ha there was a marked improvement especially at Kadawa where broad leaved weeds were the main probem and where the seed cotton yield from this treatment was the highest.

Diuron at 0.8 kg/ha followed with MSMA was comparable with norflurazone at 1 kg/ha followed with MSMA at Samaru but inferior at Kadawa. At 1.6 kg/ha, however, diuron killed 68% of cotton plants at Samaru and was the lowest yielder of all the herbicides. At Kadawa there was an improvement in cotton stand as a result of supplying missing stands 2 weeks later, after an initial kill of 31% cotton plants and seed cotton yield was also respectable. It appears that split application of diuron or application 2-3 weeks before sowing cotton might be better.

In the absence of any hoe weeding or herbicides the weeds produced a big tonnage and shaded the cotton completely with practically no seed cotton yield at both locations.

Table 51b. Effect of Herbicides on Weed Cover, Crop Vigour and Pod Yield of Groundnuts[1]

Treatment	Weed Cover 6 wk. later		Weed Cover at Harvest		Crop Vigour 6 wk later		G.Nut Pods
	Score[4]	Square root[6]	Score[4]	Square root[6]	Score[5]	Square root[6]	(kg/ha)
1. Vernolate at 3 kg/ha ppi	5.4	2.42 bc	7.6	2.85 cd	5.4	2.42 cd	262 c
2. Vernolate at 4.5 kg/ha ppi	4.6	2.26 b	7.3	2.80 bcd	5.7	2.48 bcd	227 c
3. Vernolate at 6 kg/ha ppi	3.6	2.03 ab	7.0	2.74 bcd	5.0	2.35 d	360 abc
4. Alachlor at 1.5 kg/ha pre - em.	5.3	2.40 bc	7.6	2.85 cd	5.7	2.40 bcd	295 bc
5. Alachlor at 3 kg/ha pre - em.	4.3	2.18 b	7.0	2.74 bcd	6.7	2.68 ab	449 ab
6. " " 4.5 kg/ha pre - em	2.3	1.68 a	5.7	2.48 b	6.3	2.61 abc	263 c
7. Trifluralin at 0.8 kg/ha ppi	7.0	2.74 cd	7.3	2.80 bcd	5.0	2.35 d	205 c
8. Trifluralin at 0.8 kg/ha ppi + Cyperquat[2] at 2 kg/ha post - em	7.3	2.83 d	6.3	2.61 bc	5.4	2.42 cd	338 abc
9. Hoe weeded (twice)[3]	4.3	2.20 b	3.3	1.95 a	7.0	2.74 a	489 a
10. Unweeded	9.0	3.08 d	8.7	3.03 d	5.0	2.34 d	205 c
S.E.		0.12		0.10		0.07	56

1. Data in the same column followed by a common letter are not significantly different at the 5% level by using Duncan's Multiple Range Test.

2. Cyperquat applied after scoring for weed cover and crop vigour (6 weeks after sowing)
3. Only one hoe weeding had been done at the time of scoring for weed cover and crop vigour (6 weeks after sowing).
4. Scoring scale 0 - 9 where 0 =no weeds, and 9 = full weed cover.
5. Scoring scale 0 - 9 where 0 = completely killed, and 9 = completely healthy crop
6. Data transformed to square roots $x = \sqrt{x + \frac{1}{2}}$ for analysis.

Study of the residual effects of herbicides applied during the rains

Tomatoes were intertransplanted towards the end of harvest of cotton crop on the shoulders of ridges on both sides to see the residual effects of herbicides on this crop and also to see the possibility of having a dry season crop after a long duration crop of cotton. The tomato yields are given in table 51c2. No significant differences in yield were observed at Samaru, although perfluidone seems to have some reduction effect on tomato yield. This herbicide caused definite toxicity with marked symptoms on tomato plants at Kadawa with a consequent reduction in yield. During the last year, it caused a significant reduction in tomato yield at Samaru. Thus tomatoes cannot be intertransplanted safely after perfluidone which otherwise is a good cotton herbicide.

Table 51c2

Residual Effects of Herbicides Applied in Cotton on the Following Crop of Tomatoes[1]

Treatment	Marketable Tomatoes (Tons/ha)	
	Samaru	Kadawa
1. Perfluidone 2	33.4	20.3 c
2. Perfluidone 4	36.9	11.6 d
3. Norflurazone 1	38.7	25.2 bc
4. Norflurazone 2	42.5	32.5 ab
5. Norflurazone 1 + MSMA 2	42.9	39.7 a
6. Diuron 0.8 + MSMA 2	44.0	33.1 ab
7. Diuron 1.6 + MSMA 2	45.9	25.4 bc
8. Hoe weeded	41.2	37.2 a
9. Unweeded	41.4	36.4 a
S.E.	3.6	2.7

1 Data in the same column followed by a common letter are not significantly different at the 5% level by using Duncan's Multiple Range Test.

These results indicate the possibility of having a dry season crop of tomatoes when intertransplanted in cotton but needs further agronomic investigations.

Current recommendation

Nil

Proposed interim recommendation

- Perfluidone at the rate of 3 kg ai/ha, on medium textured soils, applied pre-emergence, provided the area is not grown with tomatoes during the same year.
- Norflurazone at 1 kg ai/ha applied pre-emergence on medium textured soils followed with MSMA at 2 kg ae/ha as a directed post-emergence spray, if and when weeds appear, but before first bloom of cotton.

H.III/5/1d. Effect of herbicides on weed control in tomatoes

Glyphosate at 1 or 2 kg/ha with or without 5 kg/ha of ammonium sulphate but all followed with 0.8 kg/ha of a proprietary mixture 'Sencor - Combi' post-emergence, pebulate at 3 or 6 kg/ha pre transplant incorporated and Sencor - Combi at 1 or 2 kg/ha pre-emergence were compared with two hoe weedings in tomato cultivar Roma at Samaru. The experimental area was infested with sedges and annual grasses.

None of the herbicides (combinations) gave a reasonably long duration control of weeds and thus the yields from those plots were very poor as compared with two hoe weedings. On the other had Sencor-Combi at 0.8 kg/ha killed all the tomato plants apart from having no effect on the later growth of weeds after a good early weed control by glyphosate at 2 kg/ha with or without ammonium sulphate but 1 kg/ha when mixed with 5 kg/ha of ammonium sulphate (Table 51d).

Current recommendation: Nil
Proposed recommendation: Nil.

Table [illegible]. Effect of Herbicides on Weed and Seed Cotton Weights (kg/ha), Weed Cover and Percent Stand of Cotton[1]

Treatment	Samaru				Kadawa			
	Cyperus spp[2]	Total Weeds[2]	Stand at Harvest	Seed Cotton	Weed Cover at Harvest[3]	Stand 2 wks after sowing	Stand at Harvest	Seed Cotton
1. Pendimethalin at 2 kg/ha pre-em	638 ab	1153 bc	94.2 a	1174 cde	4.25 cd	93.5 a	91.3	1487 b
2. Pendimethalin at 4 kg/ha pre-em	420 a	694 ab	92.9 a	1918 a	2.25 ab	94.6 a	92.9	2011 a
3. Norflurazone at 1 " "	988 c	2254 d	93.8 a	1796 ef	6.50 e	93.2 a	93.3	748 c
4. " " 2 " "	818 bc	1323 c	83.8 a	1014 de	5.50 de	92.9 a	87.5	1354 b
5. Norflurazone at 1 kg/ha pre-em + MSMA at 2 kg/ha post-em	317 a	726 ab	96.7 a	1447 bcd	2.75 b	97.0 a	93.3	2018 a
6. Diuron at 0.8 kg/ha pre-em + MSMA at 2 kg/ha post-em	353 a	529 a	92.5 a	1475 abc	4.00 c	91.9 a	91.7	1557 b
7. Diuron at 1.6 kg/ha pre-em + MSMA at 2 kg/ha post-em	748 bc	1017 abc	32.1 b	1528 f	1.75 ab	69.1 b	82.5	1679 ab
8. Hoe weeded (twice)	502 ab	809 abc	89.6 a	1848 ab	1.50 a	95.8 a	92.1	1917 a
S.E.	101	164	4.0	144	-	3.0	3.2	112
Unweeded	192	4381	68.8	27	9.00	95.2	89.2	111

1. Data in the same column followed by a common letter are not significantly different at the 5% level by using Duncan's Multiple Range Test.
2. Weed samples taken 12 weeks later and are reported as kg/ha on oven dry basis.
3. Scored on a 0 to 9 scale where 0 = free of weeds, and 9 = fully covered with weeds. Data transformed to square roots $= \sqrt{x + \frac{1}{2}}$ for analysis but are reported as the average of original score.

H.III/9/10. Control of weeds in wheat

Two trials were [illegible] at Samaru and Kadawa. Wheat cv Sidi Carres was used at both locations. Samaru site was heavily infested with C. [illegible] while that of Kadawa had mostly Portulaca oleracea with few annual grass weeds present. Scanty growth of C. [illegible] was also noticed here.

At Samaru, diuron at 0.8 or 1.6 kg/ha pre-emergence, applied to take care of annual grasses caused toxicity and yield reduction of wheat. Thus the lack of wheat competition encouraged the growth of C. [illegible]dus which is evident from table 5[illegible]. When post-emergence herbicides, mecoprop and 2, 4-D, were applied after diuron there was a significant reduction in the weed growth. In general, 2,4-D was less active than mecoprop but was comparable when following 0.8 kg/ha of diuron. In other words, a weaker herbicide like 2,4-D could still be effective in the presence of a better established crop. 2,4-D was also better tolerated by wheat.

At Kadawa, a number of pre- and post-emergence herbicides were used on a moderately weedy site. Of the 3 residual herbicides used, fluorodifen at 1.6 and 3.2 kg/ha and chlortoluron at 1.6 kg/ha were tolerated by wheat (table 5[illegible]2). They also lowered the weed weight by more than 90 percent. On the other hand diuron at both rates and chlortoluron at 3.2 kg/ha caused partial kill of the crop, especially at the lower ends of the plots, but the toxic effects did not persist as at Samaru presumably due to more leaching on a lighter textured soil. The crop recovered from an initial injury by these herbicides/rates.

Amongst the post-emergence herbicides tested at Kadawa, better weed control was obtained with 3.2 and 1.6 kg/ha of mecoprop followed with 2.4 kg/ha of bentazone. 2,4-D did not prove very effective on P. oleracea but no reduction in yield was noticed.

It is premature to draw any conclusions but wheat showed a good competitive ability and under good management it may be possible to raise a good crop without any weeding or herbicides. A number of herbicides have shown promise and can be used in case there is a need.

Current recommendation

Nil

Proposed recommendation

Nil

Table 51d. Effect of Herbicides on Weed Cover and Marketable Tomato Yield[1]

Treatment	Weed cover at Harvest Score[2]	Square root[3]	Marketable Tomatoes (Tons/ha)
1. Glyphosate at 1 kg/ha ppwf[4]	8.3	2.96 e	0
2. " " 2 " ppwf	5.5	2.45 bc	0.1
3. " " 1 " " with 5 kg/ha Am. sulphate	6.5	2.64 cd	0.2
4. Glyphosate at 2 kg/ha ppwf with 5 kg/ha Am. sulphate	6.0	2.55 bcd	0
5. Sencor-Combi at 1 kg/ha pre-em.	6.2	2.59 bcd	2.2
6. Sencor-Combi at 2 kg/ha pre-em.	5.0	2.34 b	5.8
7. Pebulate at 3 kg/ha ppi	7.0	2.74 de	2.9
8. " " 6 " "	5.5	2.45 bc	3.5
9. Hoe weeded (twice)	3.2	1.93 a	16.7
10. Unweeded	8.0	2.92 e	2.1
S.E.		0.09	

1. Data in the same column followed by a common letter are not significantly different at the 5% level by using Duncan's Multiple Range Test.

2. Scoring scale 0 -9 where 0 = no weeds, and 9 = fully covered with weeds.

3. Data transformed to square roots $x = \sqrt{x + \frac{1}{2}}$ for analysis.

4. All Glyphosate treatments followed with sencor-combi at the rate of 0.8 kg/ha post-emergence.

Table 59 a1. Effect of Herbicides on Weed Weight, Wheat Grain and TDM Yield (kg/ha) at Samaru[1]

Treatment	Total weeds[2]	*C. rotundus* component[3]	Wheat Grain	Wheat TDM
1. Diuron 0.8 kg/ha pre-em.	760 ef	98.1	1321 bcd	4629 bc
2. " " + mecoprop 1.6 post-em.	146 bc	100.0	1318 bcd	4333 bc
3. " " + " 3.2 "	48 a	100.0	1232 bcd	4125 bc
4. " " + 2,4-D 1.2 "	102 bc	100.0	1860 ab	5875 ab
5. " " + " 2.4 "	83 abc	82.7	1126 cde	4333 bc
6. Diuron 1.6 kg/ha pre-em	1029 ef	100.0	747 def	2167 cd
7. " " + mecoprop 1.6 "	202 d	100.0	425 f	1167 d
8. " " + " 3.2 "	56 ab	100.0	493 ef	1333 d
9. " " + 2,4-D 1.2 "	467 e	97.7	818 def	2958 cd
10. " " + " 2.4 "	163 d	96.9	758 def	2458 cd
11. Hoe weeded (once)	226 d	100.0	2040 a	7083 a
12. Unweeded	154 cd	82.7	1778 abc	6083 ab
S.E.	tr		238	666

1. Data in the same column followed by a common letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

2. Weed weights at the time of heading (oven dry basis). Data transformed to logarithm $x = \log_e x + 1$ for analysis.

3. Percent of total weeds.

Table 32. Effect of Herbicides on Weed Weights, Wheat Grain and TDM Yield (kg/ha) at Kedama[1]

Treatment			Total Weeds[2]	Weed Composition (% of total) Broad lvd.	Grasses	Sedges	Wheat Grain	Wheat TDM
1. Chlortoluron at	1.6	pre-em.	31 a	54	28	18	2916	6448
2. "	3.2	"	138 abcd	16	4	80	2450	5510
3. Diuron at	0.8	"	78 abcd	32	58	10	2734	6167
4. "	1.6	"	147 bcde	22	40	38	2819	6052
5. Fluorodifen	1.6	"	44 abc	42	46	12	2822	6344
6. "	3.2	"	32 a	56	44	0	2644	5885
7. Bentazone at	1.2	post-em	247 def	74	24	2	2388	5156
8. "	2.4	"	151 cde	17	77	6	2859	6677
9. Mecoprop at	1.6	"	134 cde	62	32	6	2903	6479
10. "	3.2	"	44 ab	27	73	0	2434	5427
11. 2,4-D Na at	1.2	"	361 f	79	21	0	3291	7563
12. "	2.4	"	350 ef	80	20	0	2609	5854
13. Hoe weeded (once)			63 abc	66	34	0	3056	6823
14. Unweeded			500 f	82	18	0	2550	5844
S.E.			tr				228	549

1 Data in the same column followed by a common letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

2 Weed Weights at the time of heading (oven dry basis). Data transformed to logarithm $x = \log_{10} x + 1$ for analysis.

Sub-Project H.III/5/2 - Integrated control of Cyperus spp.

Objective: To evaluate various cultural, mechanical and chemical control measures and to develop their integrated use in Cyperus infested areas.

Starting Date: 1974

Researcher(s): A.H. Choudhary

H.III/5/ Effect of cultivation and herbicides on the control of Cyperus rotundus and Cyperus esculentus in a rotation.

A three-year rotation including crops likely to be grown in irrigated areas viz. Maize - Tomatoes - Groundnuts - Wheat - Cotton - Fallow is being followed in the experiment. The lay out is such that all crops will be grown once in each year. The first crops of maize, groundnuts and cotton were sown in the wet season of 1976 as main plots and were replicated twice. The sub-plots are a factorial arrangement of two cultivation and three herbicide treatments, the details of which are given in table 52a1. There could not be any difference in H_1 and H_2 treatments in the first wet season and the data from the two treatments were grouped together and has been shown as one treatment (H_1 and H_2). Wet season crops were followed with tomatoes, wheat and fallow, respectively, in the dry season.

A big increase was observed in maize and tomato yield with intensive cultivation (table 52a2). This obviously was the result of decreased and/or weaker cyperus growth in plots receiving extra cultivations. On the other hand maize showed severe nutrient deficiency symptoms in C_0 treatments, being unable to withstand the competition from cyperus plants. Cotton was the other crop which was slightly benefitted from intensive cultivation. Groundnuts and wheat did not show any response to extra cultivations. This seems to be due to low nutrient demand of the former and greater competitive ability of the latter crop. It was intresting to note in case of maize and tomatoes that the performance of herbicides was poor on standard seedbeds and this could be one of the reasons of failure to get a satisfactory weed control with herbicides.

Change in Cyperus population was observed (table 52a3), apart from getting difference in crop yield. The reduction in cyperus population was greater with intensive cultivations in each of he sequences. An increase of 42 percent was noted in the maize - tomato sequence, on the other hand, under standard cultivation. Groundnut - wheat seems to be the best part of the rotation when reduction in cyperus population is considered.

Although this was first year of the study, it has clearly demonstrated the importance of cultivation in management of soils infested with perennial sedges. Herbicides did not contribute in lowering the weed population although helped to get crop yields comparable with hoe weeded plots which was not unexpected because they mostly suppress the tuber growth rather than their kill.

Current recommendation

Nil.

Proposed recommendation

Nil.

Table 4.1. Detail of Treatments Applied in Cultivation x Herbicides Trial

A. Cultivation Treatments:

Date	Operation	
	Standard cultivation (C_0)	Intensive cultivation (C_1)
5/5/76	All plots disc and spring harrowed	
28/5/76	-	Rotary Cultivated (once)
31/5/76	-	Rotary Cultivated (twice)
13/6/76	All plots rotary cultivated (twice)	
14/6/76	All plots harrowed to mix fertiliser	
15/6/76	All plots ridged	
5/11/76	-	Plots for tomatoes and wheat rotavated (twice)
19/11/76	-	Above plots rotavated (once)
25/11/76	Plots irrigated	-
6/12/76	Plots rotavated (twice)	-
6/12/76	All plots rotavated (once), ridged and some ridges for wheat plots levelled to make basins	
20/1/77	-	Plots vacated by cotton irrigated
28/1/77	-	Above plots tine cultivated (twice)
4/3/77	-	Above plots rotavated (once)
29/5/77	All plots disc harrowed	

B. Herbicide Treatments:

H_0 = Hoe weeding as follows:

Maize, Groundnut, Cotton and Tomatoes } - 2 hoe weedings to each crop.

Wheat - one hoe weeding

H_1 = Herbicides on wet season crops only:
Maize - 6 kg/ha butylate + 2 kg/ha atrazine ppi.
Groundnuts - 3 kg/ha alachlor pre-em followed with 2 kg/ha cyperquat post-em.

Cotton - 3 kg/ha perfluidone pre-em.

Dry season wheat hoe weeded once and tomatoes hoe weeded twice.

H_2 = Herbicides on dry season crops in addition to wet season:

Wheat - 1 kg/ha diuron pre-em. followed with 3 kg/ha mecoprop post-em.

Tomatoes - 4 kg/ha pebulate ppi. (Also one hoe weeding given due to very high weed population).

Table 52a. Effect of Cultivation x Herbicides on Crop Yield.

Maize Grain (kg/ha):

Cult. \ Herb.	H_0	H_1 & H_2	Cult. av.
C_0	3295	3585	3490
C_1	5383	6259	5771
Herb. av.	4339	4922	

Groundnut Pods (kg/ha):

Cult. \ Herb.	H_0	H_1 & H_2	Cult. av.
C_0	2148	2440	2294
C_1	1924	2296	2110
Herb. av.	2036	2368	

Seed Cotton (kg/ha):

Cult. \ Herb.	H_0	H_1 & H_2	Cult. av.
C_0	2130	2164	2147
C_1	2615	2491	2553
Herb. av.	2373	2328	

Tomato Fruits (Tons/ha):

Cult. \ Herb.	H_0	H_1	H_2	Cult. av.
C_0	41.9	40.4	34.8	39.0
C_1	58.5	48.8	62.1	56.5
Herb. av.	50.2	44.6	48.5	

Wheat Grain (kg/ha):

Cult. \ Herb.	H_0	H_1	H_2	Cult. av.
C_0	2804	2416	2271	2497
C_1	2448	2174	2255	2292
Herb. av.	2626	2295	2263	

Table 53.3. Effect of Cultivation x Herbicides on the Number of Cocurus Plants (% of last year)

A. Average of all sequences:

Herb. / Cult.	H_0	H_1	H_2	Cult. av.
C_0	84.4	87.9	98.6	90.3
C_1	27.5	38.5	39.3	35.1
Herb. av.	56.0	63.2	68.9	

B. Cultivations x sequences:

Seq. / Cult.	Seq_1	Seq.2	Seq.3	Cult. av.
C_0	142.2	52.6	76.1	90.3
C_1	50.9	26.9	27.4	35.1
Seq. av.	96.6	39.8	51.7	

C. Herbicides x sequences:

Seq. / Herb.	Seq.1	Seq.2	Seq.3	Herb. av.
H_0	93.8	26.6	47.5	56.0
H_1	91.8	43.6	54.2	63.2
H_2	104.1	49.2	53.5	68.9
Seq. av.	96.6	39.8	51.7	

D. (Cultivations x Herbicides) x Sequences:

Seq. / C x H	Seq.1	Seq.2	Seq.3	C x H av.
C_0H_0	146.6	37.2	69.5	84.4
C_0H_1	123.9	52.3	87.6	87.9
C_0H_2	156.1	68.4	71.2	98.6
C_1H_0	41.0	16.0	25.5	27.5
C_1H_1	59.8	34.8	20.8	38.5
C_1H_2	52.0	30.0	35.9	39.3
Seq. av.	96.6	39.8	51.7	

H.III/5/2b. Effect of plant population and spacing of maize on the growth of Cyperus spp. and other weeds.

Maize CV NCA was sown in all combinations of 37, 62 and 93 thousand plants/ha with row spacings of 45, 60 and 90 cm in the years 1975 and 1976. The experimental crop received a blanket application of 6 kg/ha of butylate and 2 kg/ha of cyanazine in 1975 and 4 kg/ha of butylate plus 2 kg/ha of atrazine in 1976, applied pre-sowing and incorporated with a tractor drawn spring tooth harrow. The result for the two years are given in table 52b1 and summarized in table 52b2.

There was little regrowth of C. esculentus (the only Cyperus spp. present in the presence of a high rate of butylate in 1975 (table 52b1). Moreover, the weed samples were taken at the end of the crop and Cyperus plants at that time are overtaken by the annual weeds, dry cut and mostly disappear from the fields. Still growth differences in C. esculentus were recorded and there was a reduced regrowth with an increase in maize population. Same trend was observed in C. rotundus and annual sedges in 1976, when the weed samples were taken at the time of tasseling of maize, although the differences were not significant. Row spacing had a significant effect on the growth of Cyperus spp. in 1976 and weight of Cyperus spp. recorded in 90 cm row spacing was double than 45 or 60 cm rows.

Row spacing had a significant effect on the total weed growth in both years and the weed weights were higher when maize was sown in rows 90 cm apart as compared with 45 or 60 cm rows. Similarly there was lower weed growth at higher populations (table 52b2).

Considering the grain and total dry matter yield of maize and its effect on weed growth (table 52b2) it appears that medium population and row spacing will be more beneficial than the lower and higher populations and spacings. Apart from depressing the weed growth to a reasonable extent, they have operational advantage, produce good sized ears combined with good yield.

Current recommendation

37,000 plants of maize per hectare grown at a spacing of 90 cm between ridges/rows and 30 cm between plants in a row.

Proposed interim recommendation

When herbicides are used for weed control, maize should be grown at a spacing of 60 cm between rows and 30 cm between plants in the rows (giving a population of 55,555 plants/ha).

H.III/5/2c. Efficient use of glyphosate for the control of Cyperus spp.

Glyphosate not only gives a seasonal control of Cyperus spp. but also reduces their population by killing the underground propagating tubers of the weed. The experiment designed to see whether ammonium sulphate tank mixed with glyphosate can increase its toxic action and whether application of nitrogenous fertilizer to promote the growth of Cyperus spp. will make it more susceptible to glyphosate, was initiated in 1975.

The treatments in 1976 were 0.5, 1 and 2 kg/ha of glyphosate applied in 300 l water/ha (G treatments), 0, 5 and 10 kg/ha of ammonium sulphate (S treatments), and 0, 25 and 50 kg/ha of N(N treatments). The experiment was conducted as a 3^3 factorial with higher order interaction confounded.

Table 52 b1 Effect of Maize Populations x Spacings on Cyperus spp. and Total Weed Weight, Maize Grain and TDM in kg/ha[1]

Treatment	Cyperus spp.[2]		Total Weeds[2]		Maize Grain		Maize TDM	
	1975[3]	1976	1975[3]	1976	1975	1976	1975	1976
37,000 plants/ha	8.6 b	844	1,072 c	1008	6,039 b	6,379 b	12006 b	12677 b
61,700 "	4.1 ab	610	371 b	828	6,811 a	7,006 a	13940 a	14273 a
92,600 "	3.3 a	472	225 a	617	6,132 b	6,502 b	13179 a	13921 a
S.E.		133		143	166	159	313	372
45 cm row spacing	5.0	521 a	424 a	688 a	6,584	6,574	13693 a	13578
60 cm row spacing	5.2	424 a	576 ab	595 a	6,204	6,872	12695 b	14153
90 cm row spacing	5.8	981 b	669 b	1170 b	6,193	6,440	12726 b	13140
S.E.		133		143	166	159	313	372
37,000 plants/ha at 45 cm space	9.0	602	921	799	6,389 ab	6,224 bcd	12683	12636
" " " 60 " "	5.4	526	1,188	620	5,525 bc	6,080 cd	11219	12484
" " " 90 " "	11.4	1406	1,108	1606	6,214 abc	6,831 abc	12101	12911
61,700 " " 45 " "	3.2	639	299	799	6,821 a	6,512 bc	14601	13470
" " " 60 " "	4.3	345	379	606	6,615 a	7,613 a	13495	15049
" " " 90 " "	4.6	847	436	1079	6,996 a	6,903 abc	13734	14300
92,600 " " 45 " "	2.8	324	50	468	6,553 a	6,986 ab	13799	14627
" " " 60 " "	5.8	401	160	558	6,471 a	6,924 abc	13382	14925
" " " 90 " "	1.4	693	464	824	5,370 c	5,607 d	12348	12209
S.E.	tr	231	tr	247	287	276	542	645

1. Data in the same column (between populations, row spacing and their interaction) denoted by a common letter are not significantly different at the 5% level by using Duncan's Multiple Range Test.

2. Weeds removed from the sample areas at the end of harvest in 1975 and at tasselling time of maize in 1976.

3 - Analysis done on transformed data.

Table 52 b 2 Effect of Maize Population x Spacing on Average Weed Weight, Maize Grain and TDM

A Average weed weight (kg/ha)

Pop \ Spac	45 cm	60 cm	90 cm	Av. Pop.
37,000	860	900	1357	1040
61,700	549	499	757	599
92,600	259	359	644	421
Av. Spac.	556	585	919	Over all Av 687

B Average Maize Grain (Tons/ha)

Pop. \ Spac.	45 cm	60 cm	90 cm	Av. Pop.
37,000	6.3	5.8	6.5	6.2
61,700	6.7	7.1	7.0	6.9
92,600	6.8	6.7	5.5	6.3
Av. Spac.	6.6	6.5	6.3	Over all Av. 6.5

C Average Maize TDM (Tons/ha)

Pop \ Spac	45 cm	60 cm	90 cm	Av. Pop.
37,000	12.7	11.8	12.5	12.3
61,700	14.0	14.3	14.0	14.1
92,600	14.2	14.2	12.3	13.6
Av. Spac.	13.6	13.4	12.9	Over all Av. 13.3

The experimental area was disked and harrowed in the middle of May and the N treatments were applied. In addition, atrazine was applied on the entire experimental area at 1 kg/ha to take care of weeds other than Cyperus spp. to encourage Cyperus growth. C. esculentus was the most dominant species while there were few C. rotundus plants present in the experimental area. Glyphosate and ammonium sulphate were applied in the middle of June and all Cyperus was slashed in the end of June after scoring for its control. Maize Samaru 1, 2, 3 was sown a day later at 25 cm spacing in rows 60 cm apart.

The experimental plots started to get covered with annual weeds in August. The plots were therefore sampled for weed weights in the middle of August and the entire experimental area weeded about 7 weeks after sowing. No further weeding was done till harvest.

Glyphosate acted quickly with an increase in its rate, mixing ammonium sulphate in the tank or pre-application of nitrogenous fertilizer to the soil. The weight of Cyperus plants recorded 7 weeks later indicated that 0.5 kg/ha of glyphosate was not effective while there was no significant difference in the two higher rates. There were indications of lower cyperus weights with ammonium sulphate and nitrogen fertilization but were not as marked. Part of this could be attributed to the high variablility in the experiment. Another reason could be more vigorous and healthy growth of Cyperus plants as a result of less early competition in case of these treatments.

There was an increase in maize yield when glyphosate was tank mixed with 5 or 10 kg/ha of ammonium sulphate as well as application of 50 kg of extra N. Also 2 kg/ha of glyphosate was significantly better than 0.5 kg/ha. These data further support the benefits of these treatments in getting good cyperus control. However, some of the increase in maize yield in case of N_2 must be direct effect of N on the growth of maize.

Current recommendation

Nil.

Proposed recommendation

Nil.

REPORT TO THE BOARD OF GOVERNORS ON THE INSTITUTE'S WORK IN 1975-76

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RESOURCES ON
DEVELOPING COUNTRIES

FARM SYSTEMS AND INTERCROPPING PROGRAMME

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CROPPING SYSTEMS AND INTERCROPPING PROGRAMME

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Emphasis continues to be directed to an understanding of cropping systems employed by small farmers, particularly an understanding of mixed cropping. The ultimate aim is to devise a closed system for use by the small farmers and which increases the energy output/input ratio.

Mixed cropping rotation trials could not be initiated this year because a) design difficulties and b) the extent of other experiments giving insight into facets of such rotations.

With the arrival of a Crop Physiologist and another Cereals Agronomist work has begun again studying the physiology of mixture, particularly the parts played by leaf canopy structure.

Emphasis in the weed science programme, has shifted from control of Striga by chemical means to breeding cereals for resistance. It has been found extremely difficult to develop viable means of controlling Striga by herbicides which could be applied by small farmers. The emphasis is now very much on the efficient testing of recognised herbicides for control of general weeds in crops of different soil and climatic zones. Attention is drawn here to the useful results being obtained by using herbicides applied on and with fertiliser as a means of reducing labour input from extensive carriage of water. Attention is also drawn to the good results being obtained for control of weeds under irrigation. It is felt that recommendations can be formulated from these results once proper costings have been made.

It is again disappointing that results for State trials on mixed crops have been so variable. It is clear that these experiments cannot be easily supervised by State staff. To the extent, in fact, that I.A.R. is attempting to sow and harvest many of these trials in 1976. It should, perhaps, be realised that there are two types

of trial in the States. Some of them are location specific, and thus require wide coverage prior to recommendation. Fertiliser trials, variety trials, etc., fall into this category. The other are crop specific. For example the time when a crop takes up nitrogen; or the performance of two varieties in a mixture. These are largely independent of location, and results obtained from a single location are applicable on a wide scale, thus obviating the need for extensive trials prior to a recommendation. The majority of mixed cropping experiments fall into this category. If this is recognised, and particularly since it has been found very difficult to adequately supervise complicated experiments in the States, then recommendations for mixed crops can be forthcoming very much more quickly.

The report is presented, as in past years, in three sections; Intercropping, Rotations, and Weed Control.

Intercropping

The programme is defined to answer two questions:

1) Do mixtures give greater returns than equivalent sole crops? In this context "returns" will mean cash income, although this will vary from time to time depending upon marketing factors. Return is taken as the only measure since, in the long run, the need for security will be reduced, and the value of the intercrop for efficient use of labour will also disappear, being replaced by cattle, herbicides, or even mechanisation.

2) How can mixtures be improved? I.e., how can mixtures be made to give higher returns?

To answer this question requires an understanding of why a mixture gives greater returns in the first place. Most of the work since the intercropping programme restarted in 1973 has been an attempt to answer this question.

As a baseline for investigation a cropping system with mixed crops common in the Zaria area (around Samaru) was taken. This system has been described by Buntjer and consists, essentially, of a three year cropping cycle.

Year one: Sorghum is sown on ridges whilst millet is sown in the furrow. Spacing varies, sorghum about 60 cms. apart, millet somewhat wider. Millet may be sown earlier than sorghum, depending upon how well the rains begin.

```
-S--------S--------S--------S--------S--
    M        M        M        M        M
-S--------S--------S--------S--------S--
    M        M        M        M        M
```

Year two (i): Both sorghum and millet are sown in the furrows at wide spacing, 3—4 m. Again, millet may be sown earlier than sorghum.

```
S            M            S            M
S            M            S            M
```

Year two (ii): After the rains have become established, generally some 3—4 weeks after the cereals have been sown, the field is weeded and the ridges split and reformed around the cereals. Groundnuts are then sown. The general picture becoming one of widely spaced rows of cereals at right angles to closely spaced groundnuts.

```
S~~~~~~~~~~~~M~~~~~~~~~~~~S~~~~~~~~~~~~M
S~~~~~~~~~~~~M~~~~~~~~~~~~S~~~~~~~~~~~~M
S~~~~~~~~~~~~M~~~~~~~~~~~~S~~~~~~~~~~~~M
```

This system affords very early sowing of cereals whilst collecting run-off water in the furrows; the wide spacing of the cereals further reduces competition for moisture. Cultivation of the land is delayed until the ground is soft, when weeding and ridging form a single operation; whilst the cash, groundnuts, is sown when the rains are established.

Year three: Cereals, generally millet, are sown on the ridge, and relay crops (cotton, cowpea, sweet potato, okra) are sown much

later in the season, on the same ridge under the cereal.

```
-M---------M---------M---------M---------M---------M
   C         C         C         C         C
-M---------M---------M---------M---------M---------M
   C         C         C         C         C
-M---------M---------M---------M---------M---------M
   C         C         C         C         C
```

The first experiments were with cereal mixtures as for year one. All combinations of pairs of two millet varieties (ex Ghana, maturing 75 days after sowing; ex Borno, maturing 85 days after sowing), three maize varieties (Bomo local, maturing 90 days; Samaru 123, maturing 110 days; and O 96, maturing 120 days after sowing), and one sorghum variety (Short Kaura 5912, maturing 160 days after sowing). Maize was included in these trials, although not widely cultivated in the area, because the crop has a growth curve intermediate between millet and sorghum and would, if successful, serve to improve the mixture.

The experiments were done in 1974 and 1975 using three replications of a split block design. Cereal varieties formed both rows and columns, being sown on odd numbered ridges in rows and even numbered ridges in columns. This gave two replicates of each mixture in each block, and one replicate (the leading diagonal before randomisation) of each sole crop. Analysis was simplified by harvesting odd and even numbered ridges separately to give two yield estimates for each plot, including sole crops.

Each experiment was fertilised with 300 kg. ha.$^{-1}$ of a compound fertiliser (20:10:10::N:P:K) at sowing.

Yields, given in Table 1, are expressed in equivalent areas. That is, yield from 1 ha. of one crop from a mixture is compared with yield from ½ ha. of that crop grown sole. (A farmer wants to know whether he should grow 1 ha. of a mixture, or two ½ ha. of each sole crop). Yields from each crop were analysed separately and mixing significantly increased yields of Ghana millet, Bomo local and Samaru maize, and sorghum, in 1974. Both later maturing maize varieties showed yield reductions from mixing in 1975. No other crop showed any reduction.

Table 1.

Grain yield in Kg. ha^{-1} at 14% m.c.

Crop		Grown with Ghana	Borno	B.local	S. 123	O. 96	S.K.5912
Ghana	1974	1923	1789	1788	1937	2054	2366
	1975	1125	1225	1052	1165	1214	1274
	mean	1524	1507	1420	1551	1634	1820
Borno	1974	2352	2239	2282	2042	2286	2617
	1975	1227	1129	1319	1093	1186	1214
	mean	1790	1684	1801	1568	1736	1916
B.l.	1974	3530	2786	3170	3048	3060	3780
	1975	2911	2788	3157	3157	3096	3075
	mean	3221	2787	3164	3103	3078	3428
S. 123	1974	4788	4982	4475	4341	4373	5976
	1975	2569	2238	3339	3317	2802	2673
	mean	3679	3610	3907	3839	3588	4370
O. 96	1974	3789	3430	3553	3539	3457	3770
	1975	2552	2737	3583	3081	3337	2780
	mean	3171	3084	3568	3310	3397	3275
S.K.	1974	3225	3175	3027	2489	2461	2827
	1975	2854	2562	2854	2436	1845	2267
	mean	3040	2869	2941	2463	2153	2547

(S.e. (1974 data only), Ex Ghana ± 117, ex Borno ± 221, B.l. ± 191, Samaru 123 ± 370, O 96 ± 340, Short Kaura ± 193 kg. $ha.^{-1}$).

In addition to the collection of harvest data a full growth analysis was done in 1975 in an attempt to determine which components of plant growth were contributing to gains from mixing. This data has not yet been analysed, although it is clear from the mass of data collected that gain is associated with better light utilisation because of different canopy structures. Ex Borno millet, for example, showed a marked increase in both number and weight of tillers once growth raised the canopy above that of short kaura sorghum. Similarly, short kaura sorghum showed an increase in total dry matter per plant once the earlier crop had been removed. Both responses are very similar to those obtained in spacing trials when population decreases.

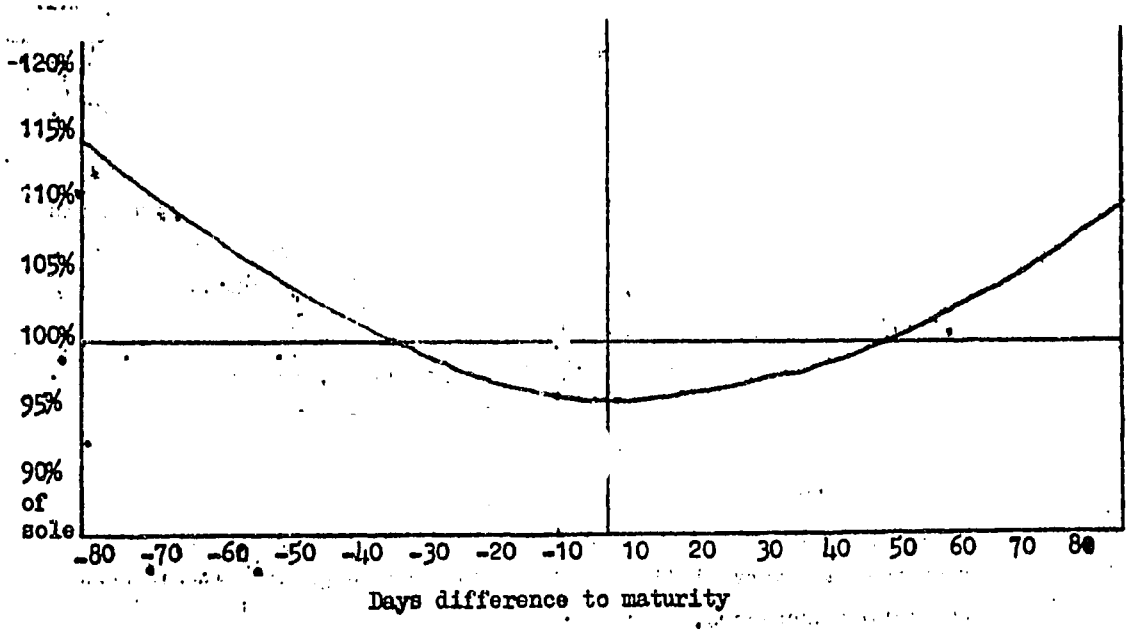
If a full analysis confirms that cereals in mixtures with different canopy structures and growth patterns behave as though they were responding to population change, then assessment of

varieties for use in mixtures can be done simply in spacing trials. Maize, for example, where log yield per plant is known to be a linear function of population (Duncan), can be assessed in two plot variety x population trials. Plastic varieties, those that maintain yield per unit area over a wide range of populations, being predictably better than non-plastic varieties. Further, since many maize varieties show prolificacy at low populations, prolific varieties may be more useful in mixtures than non-prolific varieties.

However, as an interim measure to form the basis of a recommendation, percentage gain over sole crop yield was equated with difference in days to maturity. This relationship was:

$$Y + 100 = .003035T^2 - .0238T + 95.6$$

Y = % gain; T = difference in days to maturity, negative if the crop was harvested earlier, and positive if harvested later than the other component. The relationship was highly significant for the two year data, $r^2 = .52$. The curve is shown below, and indicates that gains will only be obtained if a crop is harvested 34 or more days earlier, or 42 days or more later than the associated crop. As an early recommendation to farmers we have suggested that cereals of more than six weeks difference to maturity should be sown in mixtures.



The simple analysis of yield used above whilst indicating that gains are obtained over sole crops, does not give a picture of the mixture as a whole. Gilchrist produced an analysis, particularly

useful for the design used for these experiments, which standardised yields as ratios and produced two variables.

$$\text{"Aggressiveness"}, \quad A = \left(\frac{Y_{ij}}{Y_{ii}} - \frac{Y_{ji}}{Y_{jj}}\right)/2 \quad \text{and}$$

$$\text{"Reciprocity"}, \quad R = \left(\left(\frac{Y_{ij}}{Y_{ii}} + \frac{Y_{ji}}{Y_{jj}}\right)/2\right) - 1$$

Where Y_{ij} is the yield of variety i grown with variety j, and Y_{ji} the converse, and Y_{ii} and Y_{jj} are the sole crop yields.

Thus, if R is positive an overall gain is obtained which may be due to the aggressiveness of variety j if A is negative, or vice-versa, or the varieties may be completely compatible if A is zero.

Tables 2 and 3 give these variables for the varieties of these experiments.

Table 2. "Reciprocity = R"

Crop		Grown with Borno	B.local	S. 123	O. 96	S.K.
Ghana	1974	-.0095	.0217	.0551	.0820	.1857
	1975	.0873	-.0693	-.0984	-.0782	.1961
	both	.0389	-.0346	-.0492	-.0391	.0981
Borno	1974		.0508	.0298	.0667	.1460
	1975		-.0038	-.1826	-.0650	.1026
	both		-.0019	-.0913	-.0325	.0913
B.local	1974			-.0039	-.0034	.1317
	1975			-.0124	.0271	.1182
	both			-.0081	.0119	.1249
S. 123	1974				.0136	.1285
	1975				-.1161	-.0461
	both				-.0513	.0412
O. 96	1974					.0194
	1975					-.1629
	both					-.0912

(S.e. = 0, 1974 .0708; 1975 .1225; both .0707)

Unfortunately, variability both in and between years was too large to attribute any significance to either "A" or "R". However, the same picture emerges, that only those crops widely separated

Table 3. "Aggressiveness = A"

Crop		Grown with Ghana	Borno	B.local	S. 123	O. 96	S.K.
Ghana	1974		-.0601	-.0917	-.0478	-.0140	.0449
	1975		.0014	.0045	.1272	.1573	.0641
	both		-.0294	-.0436	.0397	.0717	.0545
Borno	1974	.0601		.0702	-.1178	.0144	.0228
	1975	-.0014		.1112	.1490	.1151	-.0286
	both	.0294		.0907	.0156	.0648	-.0029
B.local	1974	.0917	-.0702		-.0348	-.0312	.0034
	1975	-.0045	-.1112		.0113	-.0466	-.1420
	both	.0436	-.0907		-.0118	-.0389	-.0693
S. 123	1974	.0478	-.1178	.0348		-.0059	.2481
	1975	-.1272	.1490	-.0113		-.0394	-.1208
	both	-.0397	-.0156	.0118		-.0227	-.0637
O. 96	1974	.0140	-.0144	.0312	.0059		.1100
	1975	-.1573	-.1151	.0466	.0394		.0226
	both	-.0717	-.0648	.0389	.0227		.0663
S.K.	1974	-.0449	-.0228	-.0034	-.2481	-.1100	
	1975	-.0641	-.0286	.1420	.1208	-.0226	
	both	-.0545	.0029	.0693	.0637	-.0663	

(S.e. = .0, 1974 .0737; 1975 .1245; both .1510)

at harvest show any gain, particularly short kaura sorghum.

As a preliminary attempt to more clearly explain % gain, "A" and "R", such data as was available was included in a multiple regression.

Independent variables used are listed below:

1. Linear coefficient of the height curve
2. Height at maturity
3. Height at flowering
4. Age to maturity
5. Difference in days to maturity
6. (Difference in days to maturity)^2
7. Integral of leaf dry weight with time, an approximation to leaf area duration.

Where % gain was concerned the only variable of any significance was (difference in days to maturity)^2, conforming the earlier, simple regression. This gave $Y + 100 = 96.9 + .00291T^2 \pm .00047$; $r = .7149$, $r^2 = .5112$. $F = 35.55$ on 1 and 34 df. The same variable was also highly significant in explaining "R"; "R" $= .1858 + .00017T^2 \pm .000019$, $r = .8369$, $r^2 = .7004$, $F = 79.49$ on 1 and 34 df.

No one variable, or combination of variables gave an explanation for "A", the most important being the linear coefficient of the height curve. However, even the inclusion of all variables only accounted for 22% of the total variation. Yield, % gain, "A" and "R" are given in Table 4.

It is hoped that when all growth data has been analysed a more accurate picture, particularly of "A", will emerge. If the ability to compete in mixtures is simply a reflection of "better" plant structure permitting more efficient utilisation of light, water and nutrients, then rank order of varieties under sole cropping should reflect performance in mixtures.

El Rouby, comparing yield of advanced sorghum lines grown sole and with a standard millet (ex Borno), found correlations of 0.98 and 0.81 between sole crop yields and yields when intercropped for two groups of varieties. However, if $\frac{Y_{ij}}{Y_{ii}}$ was correlated with Y_{ii}, the correlations coefficients become -.2132 and -.4591, with 1 and 13 df, for the same groups of varieties. Clearly, although absolute yield in a mixture may be reflected by the absolute yield of the sole crop, the relative performance has no such correlation. This opens up many avenues of speculation.

Table 5. Performance of 1st group of advanced sorghum lines under intercropping with millet, 1975

Entry	Days to heading	No. Barren plants	% Barren plants	No. heads	Average No. tillers	Plant count Harvest	Yield t/h	Wt stalk t/h	Grain Stalk	Plant ht Cm	Wt 100k g	No. Kernels/head	Wt head g	Yield % control	Yield % sole
1. L. 1389 - 73	123	11	22	43	0.96	45	2.76	14.1	1:5:1	144	2.2	3308	72.8	64	177
2. L. 1229 - 73	123	3	6	44	1:33	33	0.92	12.1	1:13:2	149	1.8	1078	23.7	21	86
3. L. 1197 - 73	119	5	10	50	1:16	43	1.37	16.0	1:11:7	150	2.1	1480	31.1	32	128
4. L. 1266 - 73	121	13	26	49	1.17	42	2.20	13.7	1:6:2	196	2.4	2121	50.9	51	108
5. L. 1489 - 73	123	7	14	40	0.98	41	1.87	11.5	1:6:1	143	2.2	2410	53.0	44	105
6. L. 153[illegible] - 73	118	50	10	49	1.09	45	1.97	12.0	1:6:1	173	2.3	1982	45.6	46	144
7. L. 1556 - 73	115	9	18	61	1.39	44	1.80	14.1	1:7:8	165	2.5	1338	33.5	42	97
8. L. 1509 - 73	118	5	10	58	1.49	39	2.14	13.4	1:6:3	147	2.1	1992	41.8	50	107
9. L. 1606 - 73	121	3	6	54	1:15	47	2.44	13.6	1:5:6	173	2.3	2228	51.2	57	244
10. L. 181	123	8	16	77	1.60	48	3.76	17.0	1:4:5	170	2.8	1979	55.4	88	127
11. L. 1484 - 73	1191	5	10	38	1.15	33	1.70	11.8	1:6:9	181	2.9	1749	50.7	40	156
12. Wx - 60	119	6	12	87	1.89	46	2.90	18.0	1:6:2	170	2.4	1575	37.8	68	149
13. 2123	122	7	14	36	0.80	45	2.11	15.3	1:7:2	137	2.0	3323	66.4	49	157
14. SK. 5912	124	9	18	51	1.13	45	4.28	19.8	1:4:6	217	3.3	2884	95.2	100	135
15. RCFX 187	116	8	16	63	1.34	47	5.81	25.0	1:4:3	201	3.1	3374	104.6	136	121
16. 181	123	6	12	58	1.26	46	5.39	17.0	1:3:1	168	4.0	2635	105.4	126	146
Mean	120	6.9	13.8	54	1.24	43	2.71	15.2	1:5:6	168	2.5	2216	57.4		
L.S.D. 05	7	9	18	17		6	0.82	3.2	1	12	0.3				
C.V.	4	80		19		9	19	13			7				

Table 4.

Yield as kg. ha.$^{-1}$ grain at 14% m.c., % gain, "A" and "R" for sorghum Varieties

Crop		Grown with						
		R 960	R 21	187	1412	181	S.K.	FFBL
R 960	Y	1134	1235	1506	638	1017	1090	549
	%	----	+ 8.9	+38.1	-43.7	-10.3	- 3.9	-51.6
	A	----	.0604	.2326	-.1807	.0934	-.1162	-.6341
	R	----	.0286	.1480	-.2570	-.1966	-.0771	.1181
R 21	Y	1066	1101	1305	647	702	757	565
	%	- 3.2	----	+18.5	-41.2	-28.1	-31.2	-48.7
	A	-.0604	----	.2121	.0089	-.0054	-.1263	-.5240
	R	.0286	----	-.0268	-.4207	-.2751	-.2144	.0374
187	Y	2294	1908	2506	1929	2396	1927	1162
	%	- 8.5	-23.9	----	-23.0	- 4.4	-23.1	-53.6
	A	-.2326	-.2121	----	-.0735	-.0291	-.2633	-.5196
	R	.1480	-.0268	----	-.2266	-.0440	.0322	-.0166
1412	Y	1659	1204	1647	1796	1611	1549	932
	%	- 7.6	-43.0	- 8.3	----	-10.0	-13.8	-48.1
	A	.1807	-.0089	.0735	----	.1294	-.0861	-.4360
	R	-.2570	-.4207	-.2266	----	-.2323	-.0541	-.0449
181	Y	1662	1710	2374	1494	2341	1773	1129
	%	-29.0	-27.0	+ 1.4	-36.2	----	-24.3	-51.8
	A	-.0934	.0054	.0291	-.1294	----	-.0588	-.7210
	R	-.1966	-.2751	-.0440	-.2323	----	-.1839	.2034
S.K.	Y	3207	2451	3482	2781	2352	2688	2334
	%	+19.3	- 8.8	-29.5	+ 3.5	-12.5	----	-13.2
	A	-.1162	.1263	.2633	.0861	.0588	----	-.3641
	R	.0771	-.2144	.0322	-.0541	-.1839	----	.2324
FFBL	Y	3463	3086	2971	2750	3826	3156	1977
	%	+75.2	+56.1	+50.3	+39.1	+93.5	+59.6	----
	A	.6431	.5420	.5196	.4360	.7210	.3641	----
	R	.1181	.0374	-.0166	-.0449	.2034	.2324	----

(S.e. R = 0 = .1640; A = 0 = .2010)

If components of yield, as measured by usual growth analysis methods, of two varieties differing markedly in their relative performance in mixtures, can be standardised with the appropriate statistical technique, and such standardisation does not account for relative performance, then we may have to look inside the plant as well as at external morphological characters to determine those factors responsible for absolute yield.

In the last analysis farmers are interested in cash returns, and Table 6 shows total value from maize, millet and sorghum mixtures, and includes results from another experiment comparing yields from mixtures of all three crops.

Thus, provided mixtures are suitably chosen farmers can expect consistent gains from the system. It is pertinent that farmers around Zaria mostly use ex Borno millet and FFBL sorghum. Combining a fast growing, tall millet with a slower growing, long season, very tall sorghum.

Table 6.

Value of grain yield from sole and mixed crops

Mixture			Value (#)				
I	II	III	I	II	III	Total	% gain
Ghana	-	-	240.5	(235.1)			
Borno	-	-	265.7	(346.2)			
B.local	-	-	322.7	(442.5)			
S. 123	-	-	390.6	(403.7)			
O. 96	-	-	346.5	(300.6)			
S.K.	-	-	285.9	(298.8)			
Ghana	Borno	-	118.9	141.2	-	280.1	+ 11.0
"	B.local	-	112.0	164.2	-	276.2	- 1.9
"	S. 123	-	122.4	187.6	-	310.0	- 1.8
"	O. 96	-	128.9	161.7	-	290.6	- 1.0
"	S.K.	-	143.6	155.0	-	298.6	+ 13.6
Borno	B.local	-	142.1	142.1	-	284.2	- 3.4
"	S. 123	-	123.7	184.1	-	307.8	- 6.2
"	O. 96	-	137.0	157.3	-	294.3	- 3.8
"	S.K.	-	151.2	160.5	-	311.7	+ 13.2
B.local	S. 123	-	158.2	199.2	-	357.4	+ .2
"	O. 96	-	157.0	182.0	-	399.0	+ 1.3
"	S.K.	-	174.8	164.5	-	399.3	+ 11.7
S. 123	O. 96	-	183.0	168.8	-	351.8	- 4.5
"	S.K.	-	222.9	137.8	-	360.7	+ 6.8
O. 96	S.K.	-	167.0	120.5	-	287.5	- 9.0
Ghana	B.local	S.K.	96.7	111.9	130.0	338.6	+ 4.0
"	S. 123	"	96.0	151.6	113.2	360.8	+ 15.4
"	O. 96	"	106.4	155.6	121.5	383.5	+ 37.9
Borno	B.local	"	119.1	133.7	119.2	372.0	+ 2.6
"	S. 123	"	123.3	140.4	110.1	373.8	+ 6.9
"	O. 96	"	133.7	119.4	84.9	338.0	+ 7.2
B. local	S. 123	O. 96	160.8	170.1	170.7	501.6	+ 31.2

(Sole crop values in brackets are for use in calculating returns from three crop mixtures).

Optimum plant population for a crop is a balance between too small a leaf area, when most of the light penetrates the canopy and is wasted, and too large a leaf area, when mutual shading prevents efficient light utilisation.

II. In the trials described so far each component of the mixture was sown at a spacing which would have given an "optimum" population had that component been grown sole. However, because the components grow at different rates the faster growing crop, which is above the canopy of the slower growing crop, must be considered at lower than optimum. Similarly, whilst the fast growing component is present the other crop is at higher than optimum, although reducing to half optimum when the first crop is removed. Thus one, or both, of the cereals in these mixtures should be sown at higher than sole crop optimum if the full potential of mixtures is to be achieved. However, choosing treatments for population experiments is difficult as the choice will depend upon growth rates and canopies of the particular crops concerned. Since gain is associated with difference in days to maturity (whatever the real factors involved are) we used this difference to set up treatments.

For example: In a 1:1 mixture, with each component being grown at a spacing for "optimum" sole crop population, the total population was considered unity for the period of growth of the earlier crop, and half unity for the remainder of the season. Thus, "mean" population over the season was defined as:

$$\bar{P} = \frac{\frac{1}{2}M_1(P_1 + P_2) + \frac{1}{2}P_2(M_2 - M_1)}{M_2} = \frac{M_1P_1 + M_2P_2}{2M_2}$$

where M_1 and M_2 are the growing periods of the two crops in days, and P_1 and P_2 are the proportions of sole crop crop "optimum" respectively.

Thus, for a 1:1 mixture of 0.96 maize and Short Kaura sorghum each sown at sole crop "optimum" spacing

$\bar{P} = \frac{120(1) + 160(1)}{320} = .875$. Treatments were determined by setting $P_1 = 1$ for five levels of $\bar{P}$, the same for P_2, and the resultant 25 combinations arranged in a randomised block with sole crops for each population. Results from the experiment, with 0.96 maize and Short Kaura sorghum, are given in Table 7.

There was no simple relationship between $\bar{P}$ and % gain, or gross profit. However, whilst yield response by sorghum as population increase behaved similarly to response by the sole crop, although with a higher mean, maize required a higher population in the mixture to maximize yield. Optimum population for sole crop maize,

Table 7

Yields of maize and sorghum in kg. grain ha^{-1} at 14% m.c.

Proportion of sorghum sole population		Proportion of maize sole population				
		.53	.80	1.06	1.33	1.60
.65	Yield M	2541	3564	4411	2941	3987
	% gain	-19.6	2.0	29.0	- 2.3	27.8
	Yield S	984	972	1096	1146	1022
	% gain	35.0	33.3	50.3	57.2	40.2
.85	Yield M	2255	3414	4037	4760	3140
	% gain	-28.6	-2.3	18.0	58.2	.6
	Yield S	1271	1196	1221	947	1171
	% gain	58.1	48.8	51.9	17.8	45.6
1.05	Yield M	2492	3688	4511	3364	3738
	% gain	-21.1	5.5	31.9	11.8	19.8
	Yield S	1321	1445	1121	1420	1196
	% gain	57.1	71.8	33.3	68.8	42.2
1.25	Yield M	2517	3314	3788	3775	4087
	% gain	-20.3	- 5.2	10.8	25.5	31.0
	Yield S	1844	1595	1246	1221	1196
	% gain	101.3	74.1	30.0	33.3	30.6
1.45	Yield	2791	2642	3464	3941	3838
	% gain	-11.6	-24.4	1.3	- 2.3	23.0
	Yield S	1346	1371	1346	1246	1246
	% gain	35.8	38.3	35.8	25.7	32.3
Sole crop yields :	Maize	3159	3495	3420	3009	3181
	Sorghum	729	804	841	916	991

in this experiment, was .93 of that considered optimum, whilst in the mixture it was 1.28 of sole crop optimum.

Greatest profit, given in Table 8, was obtained when maize population was raised to 1.24 times normal sole crop population, whilst maintaining sorghum at the same as sole crop. (It is interesting, although premature, to speculate as to the form of a recommendation, that $\bar{P} = 1$ with these populations.)

Table 8

Gross profit in Naira from maize/sorghum mixture

Proportion of sole crop sorghum population	Proportion of sole crop maize population				
	.53	.80	1.06	1.33	1.60
.65	-52.3	.8	49.3	-22.8	23.6
.85	-50.8	4.1	37.2	58.8	-11.3
1.05	-36.0	32.0	55.8	14.1	20.6
1.25	- 5.4	21.3	25.9	23.9	38.4
1.45	-19.3	-25.5	15.0	-17.3	28.5

("A" maize $= -.7168 + .7801\bar{P} - .2259\bar{P}^2$; $r = .4584$; $r^2 = .2101$

"A" sorghum $= .2499 + .2798\bar{P} - .3472\bar{P}^2$

"R" $= -.5128 + 1.7092\bar{P} - .9004\bar{P}^2$; $r = .4203$; $r^2 = .1767$).

III. A series of trials to support those at Samaru were initiated at various State locations in 1973. Treatments were as follows:

Treatment

1. Sole maize
2. Sole sorghum
3. Sole millet
4. Alternate ridges maize and sorghum
5. Alternate pairs of ridges maize and sorghum
6. Alternate ridges sorghum and millet
7. Alternate pairs of ridges sorghum and millet
8. Alternate ridges maize and millet
9. Alternate pairs of ridges maize and millet
10. Alternate pairs of ridges maize and millet
11. Alternate pairs of ridges of maize, millet and sorghum.

All plots were fertilised with compound (21:14:14) at 570 kg. ha^{-1} split in equal amount at sowing and four weeks after sowing. Varieties used were O. 96 maize, S. Kaura 5912 sorghum, and ex.Bernu millet.

Locations were Riyom, Kafinsoli, Pankshin, Yandev, Kuje, Gumel, Panda, Kadawa.

(Logbooks and materials were not despatched to Gumel, Panda and Kadawa in 1975).

Riyom

In all three years sorghum and millet failed; sorghum was destroyed by leaf diseases in 1973, stem borer in 1974 and, although producing good heads in 1975, these were badly affected by smut. Millet was consistently bad. Heads were formed but no grain produced. This had been reported as due to bird damage but was more likely Fusarium head blight. The latter is a serious and widespread disease of millet.

Yandev

Sorghum failed in 1974 and 1975, and yielded poorly in 1973. Maize gave good yields in 1973 and 1975, yielding very poorly in 1974. Millet gave good yields in all years.

Treatments results are given in Table 9
All Yields are given on an equivalent area basis.

Table 9
Yield in kg. grain ha.$^{-1}$ for 1973, 1974

		1973			1974		1975	
		Maize	Sorghum	Millet	Maize	Millet	Maize	Millet
Sole		2776	-	-	817	-	3015	-
"		-	550	-	-	-	-	-
"		-	-	2274	-	1494	-	2127
Two crop	1)	5340	1331	-	-	-	-	-
	2)	2950	1153	-	-	-	-	-
	1)	3079	-	2303	1226	1679	2305	2227
	2)	3153	-	2137	952	2021	2239	-
	1)	-	1121	3479	-	-	-	-
	2)	-	758	2743	-	-	-	-
Three crop	1)	2266	1952	2267	-	-	-	-
	2)	2376	629	2653	-	-	-	-

S.e.	maize	± 996	± 900
	sorghum	± 406	-
	millet	± 839	± 1071

There were no significant differences in 1974 or 1975, as would be expected from poor replication because sorghum failed. Maize grown with sorghum and sorghum grown with maize both produced significant gain over sole crop yields in 1973. Millet showed no gain. In no year did any crop show significant losses as a consequence of mixing.

Panda

Both maize and sorghum failed in 1973 due to drought. There were no differences due to mixed cropping in 1974 because of very variable yields. Coefficients of variation of maize and millet were 47%, whilst for sorghum variation was 52%. Yields are given in Table 10.

Table 10.

Yield in kg. grain equivalents, ha^{-1} for 1974

		Maize	Sorghum	Millet
Sole		2841	-	-
"		-	1598	-
"		-	-	1598
Two crop	1)	904	1582	-
	2)	2195	1775	-
	1)	-	1259	1582
	2)	-	872	1549
	1)	1227	-	1226
	2)	2311	-	1175
Three crop	1)	2169	2712	1291
	2)	3202	904	3357

S.e. maize ± 1006; sorghum ± 789 millet ± 788

Gumel

The trial was not carried out in 1973 due to apparent non-delivery of seed. Sorghum virtually failed due to head smut. Remaining yields unreliable. According to the logbook yields of millet ranged as follows: Sole crop - 6682 - 6875 kg. $ha.^{-1}$, mixed with maize from 7166 - 10846 kg grain $ha.^{-1}$ and from the three crop mixture 6972 - 12395 kg grain $ha.^{-1}$ Plots had been laid out as rhomboids and it is unlikely that nett plot harvest instructions had been folowed.

Kafinsoli

Maize and sorghum failed in both 1973 and 1974.

Dambatta

Sorghum failed, and maize did not set grain in 1973.

Kuje

Mean yields were low in 1973: maize 1836 kg; sorghum 732 kg; and millet 933 kg. ha^{-1} grain at 14% m.c. Results were again variable. Maize showed a significant loss when grown in double rows with sorghum but gained when mixed with millet and sorghum. Millet also showed a loss when mixed with maize. Both sorghum and millet showed gain when mixed with each other. Yields are given in Table 11.

Table 11

Yields in kg. grain equivalents ha^{-1} 1973

		Maize	Sorghum	Millet
Sole		1874	-	-
"		-	674	-
"		-	-	1007
Two crop	1)	1586	545	-
	2)	904	670	-
	1)	-	1258	968
	2)	-	549	1432
	1)	1727	-	674
	2)	2207	-	1049
Three crop	1)	2023	807	909
	2)	2534	621	912

(S.e. maize ± 744; sorghum ± 191; millet ± 324)

The 1974 trial at Kuje was designed to compare yields from all mixtures of two sorghum varieties (R 960 and SK 5912) with two maize varieties (Romo local and 0.96). All mixtures were made with alternate rows of each crop.

R. 960 failed in both years, whilst short Kaura sorghum yielded very poorly as a sole crop. Although no treatment was significant, variability being very high, there was a consistent trend for mixtures to yield more than sole crops. Yields are given in Table 12.

Table 12

Kg. grain equivalents $ha.^{-1}$

	1974			1975		
	Maize	Maize	Sorghum	Maize	Maize	Sorghum
BL	1830	-	-	612	-	-
096		3486	-	-	1063	-
S.K.	-	-	420	-	-	177
B.l. + S.K.	3067	-	904	741	-	355
B.l. + 096	2357	4261	-	1063	966	-
096 + S.K.	4132	-	710		1611	258

s.e. B.L. ± 765; 096 ± 1296; S.K. ± 364

Kadawa

Millet failed in 1973. Yields for maize and sorghum are shown in Table 13.

Table 13.

Yields in kg. grain equivalents $ha.^{-1}$

		Maize	Sorghum
Sole		2873	-
"		-	3163
Double crop	1	2453	3422
	2	4196	1549

s.e. maize ± 852; sorghum ± 824

Treatments showed no significant difference.

The 1974 trial was unreliable due to several missing plots for miscellaneous treatments.

Pankshin

Both millet and sorghum failed in 1973. Results from 1975 are given below in Table 14.

Table 14

Yield in kg. grain $ha.^{-1}$ for 1975

		Maize	Sorghum	Millet
Sole		4942	-	-
"		-	1100	-
"		-	-	295
Two crop	1	5186	595	-
	2	5240	821	-
	1	5368	-	212
	2	3161	-	96
	1	-	906	396
	2	-	1787	272
Three crop	1	5205	1464	91
	2	5402	1416	227

(s.e. maize ± 834; sorghum ± 356; millet ± 91).

Millet yielded very poorly. There were no significant differences between any treatments.

IV. Time of application of Nitrogen and mixed cereals

Because there is evidence that millet takes up nitrogen very early and, in a mixture of millet and sorghum, with detriment to sorghum, an exploratory trial was done at Samaru in 1975. The trial compared four treatments:

a) All nitrogen applied at sowing
b) half at sowing, half at 3 weeks after
c) half at sowing, half at 6 weeks after
d) $\frac{1}{3}$ at sowing, $\frac{1}{3}$ at 3 weeks and $\frac{1}{3}$ at six weeks.

600 kg. nitrochalk ha.$^{-1}$ was applied as total nitrogen. All were given a basal dressing of 300 kg. ha.$^{-1}$ single superphosphate.

Yields in kg. grain ha.$^{-1}$ are given in Table 15

Table 15

Maize	0	0 + 3	0 + 6	0 + 3 + 6
Sole	6547	6653	6950	6825
+ S	5603	4899	5651	5809
+ mi	6621	6330	7554	5809
Sorghum	**0**	**0 + 3**	**0 + 6**	**0 + 3 + 6**
Sole	2241	3247	2646	2386
+ ma	1487	1867	1642	1304
+ mi	2664	2812	3270	2368
Millet	**0**	**0 + 3**	**0 + 6**	**0 + 3 + 6**
Sole	1766	1799	1771	1537
+ ma	1319	1408	1537	1619
+ S.	1540	1804	1502	1518

s.e.	Sole, mixed.	Maize	±	1567
		Sorghum	±	1091
		Millet	±	433
s.e.	Time of app.	Maize	±	458
		Sorghum	±	401
		Millet	±	294

Although results are as yet unclear both maize and sorghum gave indications that better response to nitrogen were obtained in mixture with millet when the fertiliser was applied later than sowing.

V. Mixed sorghum varieties

Experiments hitherto have demonstrated that gain in cereal mixtures is associated with better light utilisation because of different canopy structures produced by different times of harvest. Different canopy structures can also be produced by mixingvarieties which

mature at different heights. In this experiment seven varieties of sorghum were chosen for different maturity periods or heights at maturity, and mixed in all paired combinations. The varieties were:

a) R 960 106 days to maturity; approx. 1.4 m. tall at harvest.

b) R Z1 137 days to maturity; approx. 1.5 m. tall at harvest.

c) Var. 187 160 days to maturity; approx. 1.5 m. tall at harvest.

d) Var.1412 160 days to maturity; approx. 1.6 m. tall at harvest.

e. Var. 181 160 days to maturity; approx. 1.8 m. tall at harvest.

f). S.K.5912 160 days to maturity; approx. 2.5 m. tall at harvest.

g). FF. BL. 160 days to maturity; approx. 4.0 m. tall at harvest.

Yields in kg. grain ha.$^{-1}$ (equiv. area) are given in table 16.

Table 16.

Yield ha.$^{-1}$ equivalents in kg. grain

	Grown with						
	R 960	RZ1	187	1412	181	SK	FF.BL
R 960	1134	1235	1566	638	1017	1090	549
R Z1	1066	1101	1305	647	792	757	565
187	2294	1908	2506	1929	2396	1927	1162
1412	1659	1024	1647	1796	1611	1549	932
181	1662	1710	2374	1494	2341	1773	1129
S.K.	3207	2451	3482	2781	2352	2688	2334
FF.BL	3463	3086	2971	2750	3826	3156	1977

Table 17 shows yields as percentage gain of sole crop.

Table

Yields as percentage gain of sole crop

	Grown with						
	R 960	RZ1	187	1412	181	SK	FF.BL
R 960	-	+ 8.9	+38.1	-43.7	-10.3	- 3.9	-51.6
R Z1	- 3.2	-	+18.5	-41.2	-28.1	-31.2	-48.7
187	- 8.5	-23.9	-	-23.0	- 4.4	-23.1	-53.6
1412	- 7.6	-43.0	- 8.3	-	-10.0	-13.8	-48.1
181	-29.0	-27.0	+ 1.4	-36.2	-	-24.3	-51.8
S K	+19.3	- 8.8	+29.5	+ 3.5	-12.5	-	-13.2
FF.BL.	+75.2	+56.1	+50.3	+39.1	+93.5	+59.6	-

Detailed analyses have not been made and the following general statements require confirmation from repetitions of this experiment.

a) Var. 181 does not appear to be suited for mixture. All varieties, except FF.BL showed losses when grown with Var. 181, and Var. 181 showed consistent losses - with all other varieties, save Var. 187.

b) FF.BL. showed considerable gain when mixed with all other varieties although all other varieties, except S.K. 5912, showed significant losses when grown with FF.BL.

VI. Experiments designed to investigate the cereals/groundnuts mixture of the second year of the cropping system described were very much simpler, consisting each of four replications of a randomised block.

Sowing data was not used as a variable in the 1974 and 1975 trials but is to be included in additional trials of 1976. As with cereal mixtures, maize was included, and for the same reasons. These were seventeen treatments, in four groups:

i) Sole groundnuts sown 23 cm apart on 91 cm ridges; the same but with groundnut not sown at intervals of either 1.37 m. or 2.74 m.

ii) Maize (Samaru 123) or millet (Ex Ghana) or sorghum (Short Kaura) sown in place of groundnuts at intervals of 1.37 m or 2.74 m along the ridge.

iii) All combinations of pairs of maize, millet and sorghum sown alternatively at interval of 1.37 m or 2.74 m along the ridge.

iv) Maize, millet and sorghum sown in sequence at interval of 1.37 m or 2.74 m along the ridge.

The groundnut variety used was Samaru 38 and all experiments were given a seed bed dressing of 300 kg. ha.$^{-1}$ superphosphate and 0.5 kg. ha.$^{-1}$ boron. In addition, the fungicide "benlate" was sprayed to control Cercospora leaf spot - although this spray was inadequately given in 1975.

Yields of groundnut, as unshelled nuts, and cereals as grain at 14% m.c. are given in Table 19 as kg. ha.$^{-1}$ together with total value in Naira.

Removing groundnuts from sole groundnuts at intervals of 1.37 m or 2.74 m had no effect on mean yield of sole groundnut in either year. However, replacing groundnut at these intervals with a cereal significantly reduced yield of groundnut. Mean yield of sole groundnut was 2028 kg. ha.$^{-1}$ whilst mean yield of intercropped groundnuts was 1699 kg. ha.$^{-1}$ with cereals at 2.74 m, and 1484 kg.ha^{-1} with cereals at 1.37 m.

In both years sole groundnut produced significantly less cash return than mixtures overall. Sole groundnuts giving ₦443 ± 27.5, and mixtures overall giving ₦550 ± 12.8 in 1974. In 1975, despite the much increased price of groundnuts, mixtures overall gave ₦268 ± 5.2, significantly more than sole groundnuts, which gave ₦214 ± 12.7. Clearly, gicci intercropping of cereals is highly profitable as well as spreading risk of poor crop yields.

These experiments also indicate possible means of improving the mixture. Farmers frequently sow "gicci" with as much as 3 m. between lines of cereals; this approximates to the wide spacing used in these trials. Closing up the spacing by half showed gains in both years over normal practice. Overall, mixtures gave ₦601 ± 18.0 and ₦499 ± 18.0 for close and wide spacing in 1974 respectively; equivalent returns from 1975 were ₦280 ± 7.3 and ₦255 ± 7.3.

In neither year was there any difference between returns from mixtures of double, or all three cereals. However, the very

variable cereal yields mean that mixtures with more than one cereal gave greater security. In 1974 sorghum almost failed and meant that mixtures including sorghum showed no gain over sole groundnut. In 1975 millet yielded poorly and sorghum yielded well. In neither year did either crop in the mixtures result in significantly lower returns than sole groundnut. Over both years, the mixture with all three cereals was most consistent.

Finally, would the equivalent areas of the crops grown sole have given greater returns? In the mixture at close spacing the cereals occupied 16.8% of the land and groundnuts 83.2%, whilst at wide spacing they occupied 8.4% and 91.6% respectively. Table 18 shows cash returns from sole crop groundnut and cereals compared with the mixtures using average yields of 2000 kg. millet, 3000 kg. sorghum and 5000 kg. maize $ha.^{-1}$ in each year. Groundnut yields are those obtained in these experiments, as are returns from mixtures.

Table 18

Cash returns from mixtures (with all three cereals) compared with estimated returns from equivalent areas of sole crops

	Sole Crops			Mixed Crops		
	1974	1975	Mean.	1974	1975	Mean
Close spacing	₦437	₦220	₦328	₦601	₦255	₦428
Wide spacing	₦434	₦236	₦335	₦499	₦280	₦390

Thus the system is more profitable than sole crops, can be improved by sowing cereals at a closer spacing than normally used, and can be made more secure by including the third cereal, maize. This will give additional grain in the middle of the season, or more cash by being sold green.

VII. Finally the third year of the system, where the emphasis is on the cash crops cotton and cowpea. Cotton and cowpea are normally sown late in the year, generally July or August. This is despite current recommendations for June sowing. Farmers are not prepared to leave land unused until this time and it is not possible to sow cotton after cereal, unless the cereal is harvested before maturity, or unless the cotton is sown much later than optimal. This latter is often normal practice amongst farmers, and, because lower yields are obtained, spray regimes are uneconomic. This

experiment was designed to determine whether cotton could be sown earlier, within the cereal, so as to obtain the benefit accruing from early sowing, and whether spraying with insecticide would then be economic. Further, since farmers often grow cotton and cowpea mixed, both cowpea alone and mixed with cotton were included as relay treatments.

There were three main treatments: either millet or maize as the early cereal, or no cereal sown at all. Each of these included the following four treatments:

a) Cotton alone sown within the cereals, or, where no cereal had been sown, grown sole as a normal crop.

b) Cowpea alone sown within cereals, or, where no cereal had been sown, grown sole.

c) Cotton and cowpea grown in a 2:1 ratio within the cereal; i.e. cotton under-sown on two ridges, cowpea undersown on one ridge. The same mixture being also sown without being preceded by a cereal.

d) Cotton and cowpea grown in a 1:2 ratio within the cereal; i.e. cotton under-sown on one ridge, cowpea undersown on two ridges. Similarly where no cereal was present.

There were two blocks of these 12 treatments (3 early x 4 relay), one was protected against insects by U.L.V. spraying with endosulfan, the other not sprayed. Where cotton or cowpea were not mixed each was sprayed six times; with cotton and cowpea mixed they were sprayed four times.

Both millet, var. ex-Borno in 1974, and 1975 and maize, var. BS 3, were sown 23 cm. (9") apart along 91 cm. (3') ridges, and both were fertilised at sowing with 627 kg. ha.$^{-1}$ (5 cwt./acre) with the compound fertiliser 20:10:10::N:P:K. Both were sown on 7th June, 1974.

Cotton, Samaru 71, was sown on 18th July, at 45 cm. spacing either alone or beneath the cereals on the same ridge. Cotton was fertilised with 188 kg. ha.$^{-1}$ (156 lb./acre) boronated Rustica compound fertiliser (12:12:17:2::N:P:K:Mg plus 0.6% B) when the cotton was sown.

Cowpea, local Farinwake, was sown at 90 cm.spacing along the ridge either alone or beneath the cereals on the same ridge. Cowpea was not given additional fertiliser.

Table 19

Yield of G'nut (kg. unshelled nuts); cereals (kg. grain at 14% m.c.) ha.$^{-1}$ and total value (G'nut. ₦24.55** maize ₦10.20, sorghum ₦11.19 and millet ₦15.78 per 100 kg.) ₦13.78*

Treatment		Groundnut 1974	Groundnut 1975	Groundnut Mean	Maize 1974	Maize 1975	Maize Mean	Millet 1974	Millet 1975	Millet Mean	Sorghum 1974	Sorghum 1975	Sorghum Mean	Value 1974	Value 1975	Value Mean	% gain
Sole G'nut	-	3219	837	2028										444	205	325	-
	- 2.74	3291	797	2044										454	196	325	-
	- 1.37	3132	976	2057										432	240	336	-
+ ma	- 2.74	2629	904	1766	1332	400	866							496	329	413	+27.1
"	- 1.37	2228	704	1466	2346	840	1593							546	412	479	+47.4
+ mi	- 2.74	2323	673	1498				1150	116	633				502	184	343	+ 5.5
"	- 1.37	2447	708	1578				2486	182	1334				729	203	466	+43.4
+ SO	- 2.74	2515	766	1641							729	766	748	428	274	351	+ 8.0
"	- 1.37	2609	668	1639							1245	1391	1318	499	320	409	+25.8
Ma + so	- 2.74	2695	835	1765	365	152	258				153	446	299	426	270	348	+ 7.1
" + "	- 1.37	1970	638	1304	887	431	659				615	756	685	431	285	358	+10.2
Ma + mi	- 2.74	2974	737	1856	703	200	452	722	252	487				595	241	418	+28.6
" + "	- 1.37	2254	667	1460	1032	281	656	1840	338	1089				706	246	476	+46.5
Mi + so	- 2.74	2961	733	1847				658	70	364	322	310	316	548	226	387	+19.1
" + "	- 1.37	2257	603	1430				1216	96	656	686	710	698	580	243	411	+26.5
Ma, mi, so	- 2.74	2175	862	1519	545	155	350	795	38	416	125	224	174	495	258	377	+16.0
" " "	- 1.37	2316	701	1508	606	185	396	1939	58	998	259	484	371	715	254	485	+49.2

(₦13.78 1974 value, ₦24.55 1975 value. Mean * value based upon these).

Table 20

Treatment			Cereal			Sprayed						Unsprayed					
						Cotton			Cowpea			Cotton			Cowpea		
Cereal	Cotton	Cowpea	1974	1975	Mean	1974	1975	Mean	1974	1975	Mean	1974	1975	Mean	1974	1975	Mean
millet	-	-	2828	2172	2500	-	-	-	-	-	-	-	-	-	-	-	-
"	3	-	3316	2712	3014	231	317	274*	-	-	-	301	117	209	-	-	-
"	2	1	2885	2382	2634	227	178	202	480	661	570	197	74	136	198	285	242
"	1	2	3086	2512	2799	65	91	78	746	962	854	95	29	62	234	196	215
"	-	3	3158	2741	2950	--	-	-	788	1097	942*	-	-	-	369	5	187
maize	-	-	5827	4693	5260	-	-	-	-	-	-	-	-	-	-	-	-
"	3	-	5727	4664	5196	230	300	265*	-	-	-	345	237	291	-	-	-
"	2	1	5569	4592	5080	122	245	184	207	810	508	290	89	190	233	276	254
"	1	2	5727	4521	5124	78	82	80	622	965	794	93	35	64	320	263	292
"	-	3	5641	4707	5174	-	-	-	613	1213	913*	-	-	-	345	36	190
none	3	-	-	-	-	1161	1414	1282*	-	-	-	941	729	835	-	-	-
	2	1	-	-	-	703	531	617	713	1082	898	465	233	349	46	28	37
	1	2	-	-	-	281	142	212	1123	1231	1177	182	99	140	37	7	22
	-	3	-	-	-	-	-	-	1189	1358	1274*	-	-	-	2	3	3

(* = Sprayed six times)

Cereals were sown later than normal as a result of poor early rains. Thus the overlap between sowing of cotton/cowpea and harvesting of each cereal was longer than might normally be expected. These were 49 days for millet, harvested on 5th September, and 70 days for maize, harvested on 26th September.

Yields from these crops and mixtures are given in Table 20 and the nett value per hectare, after deducting fertiliser and spraying costs (but not labour), are given in table 21.

Yield of cereals was totally unaffected by the later sown crop. Yield of cotton was greatly affected by relaying and showed no compensation for a reduced population in a mixture. Cowpea, although affected by cereals, showed considerable compensation when grown as a component in a mixture. Further, and of great interest, unsprayed cowpea when sown relay gave very much higher yields than unsprayed cowpea sown alone. Observations suggest that the vigour of undersown cowpea was so much reduced by early shading from the cereal that cowpea plants were less attractive to the pest Maruca. This pest caused almost complete flower bud shedding in unsprayed cowpea sown alone.

Table 21 gives nett cash returns per hectare pricing cotton at ₦19.84, cowpea at ₦21.65, maize at ₦10.20 and millet at ₦15.78 per 100 kg. bag for 1974.

Spraying was costed at ₦7.05 per applications; ₦42.32 for the six sprays given cotton or cowpea sown alone, with or without cereal. All fertiliser was costed at a rate of ₦200/tonne.

When deducting spray cost for cotton and cowpea in a mixture the appropriate proportion was deducted from each. E.g. $\frac{2}{3}$ of the cost of spraying was deducted from the value of cotton in a 2:1 mixture, $\frac{1}{3}$ of the cost from cowpea.

Conclusions:

1. Neither cotton nor cowpea, sole or mixed, sprayed or unsprayed, gave nett returns which compensated for the absence of an early cereal.

2. Because yield of cereals, which contributed the largest amount of nett value, was not affected by relay cropping, all mixtures gave greater nett returns than cereals alone except when sprayed cotton was the only

Table 21

Nett value of crops and total returns/ha.$^{-1}$

Treatment				Sprayed			Unsprayed		
Cer.	Cott.	Cowp.	$	Cott. $	Cowp. $	Total $	Cott. $	Cowp. $	Total $
Mi	-	-	418.33	-	-	418.33	-	-	418.33
"	3	-	418.33	-19.44	-	393.89	22.26	-	440.99
"	2	1	418.33	1.56	94.53	514.42	14.37	42.87	475.47
"	1	2	418.33	- 8.85	142.72	522.20	6.49	50.66	475.48
"	-	3	418.33	-	128.29	546.62	-	79.89	498.22
Ma	-	-	517.45	-	-	517.45	-	-	517.45
"	3	-	517.45	-19.62	-	497.83	31.38	-	548.83
"	2	1	517.45	-28.69	35.18	524.18	32.85	50.44	600.74
"	1	2	517.45	6.26	155.88	627.07	6.10	69.28	592.83
"	-	3	517.45	-	90.40	607.85	-	74.69	592.14
None	3	-	-	150.97	-	150.97	149.63	-	149.63
"	2	1	-	96.00	140.27	236.27	67.57	9.96	77.53
"	1	2	-	34.00	217.11	251.12	23.77	8.01	31.78
"	-	3	-	-	215.11	215.11	-	0.43	0.43

other constituent of the mixture. Yield of cotton was so affected by relaying that spray costs were not recovered and sprayed cotton lost money.

In all cases, whether sprayed or unsprayed, cowpea gave good nett cash returns except when grown unsprayed without a preceding cereal. This crop failed.

Thus: Even in a season where the late start meant a longer than normal overlap between cereals and the relay crop, a system of cereals relayed with cowpea proved very rewarding, particularly so if maize were the preceding cereal.

VIII. One of the reasons why cotton relayed with cereals does not do well in mixtures is that emergence and subsequent growth are poor if sown under a well established canopy. Earlier experiments argued that the shorter the overlap between the cereal and cotton the more chance cotton has of establishing and producing a yield. In a second experiment cotton was intersown at different dates within cereals of different maturity periods. Sole crop cereals and sole crop cotton for each date were also sown. One treatment, hitherto not tried, was to sow cotton very early, with the cereal at the same time as the cereal. The argument being that although the cotton will be more affected by competition for light than later sown cotton, the

very early sowing may give a compensating yield due to growth before later sown cotton.

Mean yield, with values, are given in Table 22.

Table 22.

Yield of grain kg. ha.$^{-1}$ and seed cotton kg. ha.$^{-1}$ total value (All cereals sown 30th May 1975; cotton ₦30.81 per 100 kg.).

	Sole cereal	Cotton sown 30-5-75	20-6-75	11-7-75	1-8-75
Ex. Ghana	1527	1519	1470	1375	1456
Cotton	-	1236	407	419	142
₦	241	620	353	346	274
Ex. Bornu	1748	1473	1605	1435	1544
Cotton	-	687	363	306	113
₦	276	444	365	321	278
R 960	1096	995	1356	1238	1245
Cotton	-	506	82	3	0
₦	123	267	177	150	139
Bomo local	4983	4279	4575	5397	5248
Cotton	-	600	326	108	77
₦	499	614	559	586	542
Sole cotton	-	1899	(362)	1254	822
		585	(111)	386	253

It is clear that sowing cotton early at the same time as cereal holds promise.

Cereal yields were not affected by cotton. Cotton sown at the same time as cereals showed better establishment and growth kept pace with cereals for the first few weeks. Cotton habit mixed was completely different to sole cotton. Plants bore fewer and shorter branches, fewer bolls, were etiolated, and lodged heavily. Table 23 gives mean plant date for sole cotton sown on 30th May, and cotton sown within ex. Ghana millet.

Table 23

	Height cm	No. Branch	Branch length cm	No. bolls	Cm.br/ boll	Yield
Sole Cotton (30-5-75)	160.0	23.8	26.8	31.7	20.0	1899
Ex. G. Cotton 30-5-75	111.0	18.1	13.4	16.9	15.3	1236
" " 20-6-75	73.7	14.5	9.6	11.1	12.6	407
" " 11-7-75	57.0	14.5	10.3	9.8	15.6	419
" " 1-8-75	62.2	15.1	9.7	9.3	15.9	142

Although the earliest sowing of cotton was before the end of the close season (15th June) undersowing cotton in cereals at, or about, this time will remove the weeding bottleneck to sowing cotton in late June or early July. Further, because of the change of habit of the plant it may be possible to increase yields further by increasing population of cotton sown within cereals.

Rotation and Sequences

Only one experiment, begun in 1972, is carried out under this head. This trial is devised to determine the best sequence in which to grow sorghum, cotton and groundnuts.

Results to date continue to demonstrate that the best sequence, in terms of crop yield is groundnuts, sorghum, cotton: Yields are given in Table 24.

Table 24

Yield in Kg. ha.$^{-1}$ Sorghum Grains, Groundnuts Unshelled nuts and Seed Cotton

Crop	1972	1973 Following	1974 Following	1975 Following	Total	Mean
Sorghum	3095	Sorg.2474	Sorg.2048	Sorg.1236	8853	2213
		Grnt.3563	Grnt.2819	Grnt.2071	11548	2887
		Cott.2982	Cott.2449	Cott.1886	10412	2603
G/nut	3408	Sorg.2292	Sorg.1344	Sorg. 523	7567	1892
		Grnt.1454	Grnt.1231	Grnt. 367	6460	1615
		Cott.2181	Cott.1280	Cott. 584	7453	1863
Cotton	1545	Sorg.1584	Sorg. 933	Sorg. 851	4913	1228
		Grnt.1025	Grnt. 809	Grnt. 467	3847	962
		Cott.1126	Cott. 658.	Cott. 503	3832	958
Mean						
Sorghum	3095	3006	2439	1731		
G/nut	3408	1976	1285	491		
Cotton	1545	1245	800	607		

There are six sequences of interest from 1973. These are shown below with total value of crop over the three year 1973-1975. (Sorghum ₦11.19, Cotton ₦30.81 and groundnut ₦24.55 per 100 kg).

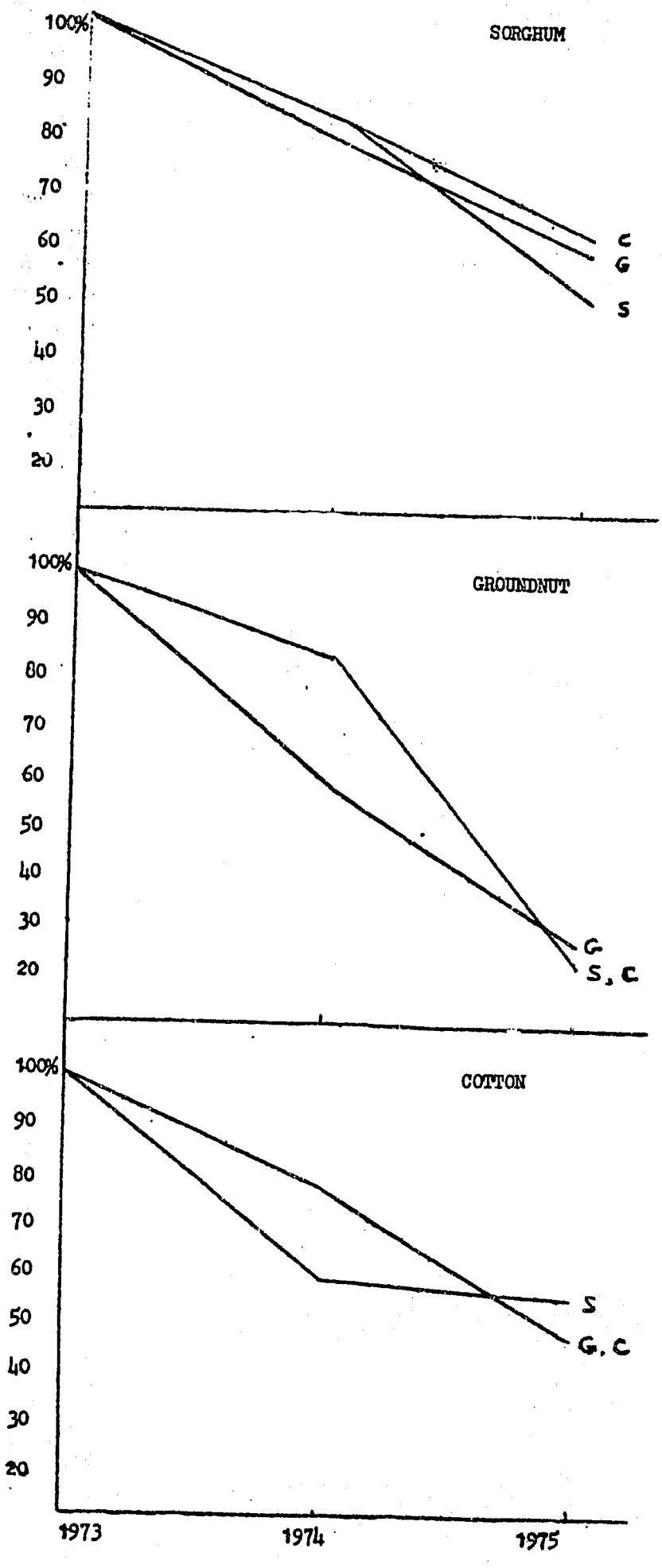
Table 25.

1973	1974	1975	Total Value
*Sorghum 3563	Cotton 933	Groundnuts 584	₦ 829.5
Sorghum 2982	Groundnuts 1344	Cotton 467	807.5
*Cotton 1584	Groundnuts 1280	Sorghum 2071	1034.0
Cotton 1026	Sorghum 2449	Groundnuts 523	718.6
*Groundnut 2181	Sorghum 2819	Cotton 851	1113.1
Groundnut 2292	Cotton 309	Sorghum 1886	1023.0

Regardless of which crop began the sequence, greatest total return was obtained from the order: groundnuts, sorghum, cotton (*)

The experiment also demonstrates a consistent linear decline in yield of all crops with time, regardless of sequence. The diagram below shows this with crop yield in 1973 given as 100%. It is to be noted that the slope of the decreasing yields is almost identical, which argues that the decrease with time is independent of crop, and thus of disease and, probably, nitrogen level. The very low levels of fertiliser used (current recommendation for each crop in each year) are clearly insufficient to maintain yield. It is particularly likely that the low phosphate level used contributed largely to the decline in yield with time.

It is intended to modify the trial in 1976 and attempt to arrest, if not reverse, the declining yields.


SORGHUM
100%
90
80
70
60
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G
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GROUNDNUT
100%
90
80
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60
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20
G
S, C
COTTON
100%
90
80
70
60
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Weed Science investigations

Introduction

There are five major projects in this field:

1. General weed control in hoe farming systems.
2. General weed control in animal draught farming systems.
3. General weed control in irrigated farming systems.
4. Control of Striga and related species of parasitic weeds.
5. Control of Imperata cylindrica.

There is no formal research into the weed problems of large scale mechanised agriculture because

a) The results from projects 2--4 can be scaled up and applied in mechanised schemes.

b) Much of the research conducted in similar ecological zones abroad can be adapted to mechanised agriculture in Nigeria with little or no research effort.

1. General Weed control in hoe farming systems

Research in this project started in 1967 when trifluralin, fluometuron and paraquat were applied in cotton at seven sites. The results were published, and showed that good weed control was obtained at most sites and that the hoe weeding task of the farmers could be reduced during the period of peak labour demand. There were, however, serious problems which have delayed the introduction of herbicides into hoe farming practice. Paraquat was too poisonous and fluometuron too persistent for use by hoe farmers. Trifluralin needs incorporation for optimum activity and was not then commercialised in Nigeria. The major problem was however to find a simple method of application which could be used by farmers. Surface active herbicides applied with knapsack sprayers need at least 220 l/ha (20 gl/ac) of water. Village water supplies are very low at the beginning of the rains but even where they are adequate the task of carrying and applying a minimum of 220 kg of water/ha represents a major addition to the farmers work-load during planting time. For these reasons the high volume application of herbicides is likely to be confined to high value crops on irrigated sites.

Granular herbicide application

Subsequent research was therefore based on the application of granular formulations. Three types of granule have been used:

1. Manufactured granules intended primarily for application in small amounts by machine. These formulations are not always available and are much more expensive to buy and transport than the wettable powder (wp) or emulsifiable concentrate (ec) formulations normally used for high volume applications. The small bulk also makes the manufactured granule more difficult to spread evenly by hand but they have been used experimentally and usually give better weed control than equivalent dosages of other granular formulations.

2. Soil granules made at village level from wettable powders or emulsifiable concentrates. These are potentially the cheapest but appropriate technology equipment has not yet been developed nor have hand mixed formulations performed very well.

3. Granular fertiliser mixed with herbicide, 'herbilisers'. These can either be made at the fertiliser factory from technical material or from the wp or ec formulations at the fertiliser selling point. These are easy and cheap to make on single superphosphate and low N compounds. The cost of transporting the herbicide is negligible because it is absorbed in the fertiliser transport cost. The large granule size and considerable bulk of fertiliser make hand broadcasting simple and easy. There is one major disadvantage to herbiliser use by hoe farmers. Rapidly maturing crops responding to placed phosphate may not respond as well to the broadcast phosphate in the herbiliser. Another disconcerting characteristic is that on phosphate responsive soils there may be a detectable increase in late weed growth caused by the weeds responding to surface applied phosphate when herbicidal activity has ceased. This is unimportant if the dosage applied reduces the hoe weeding task during the peak labour period and does not substantially increase it later in the season.

VLV application

The principle of herbicide application in ultra low volume is to use large droplets moving accurately at a controlled speed on a predictable path. This is the exact opposite of ULV insecticide application where very small droplets drift in the wind onto the

target organism. The volume usually applied with herbicides is 10 l/ha in contrast to the 2 l/ha used with insecticides. For this reason the term 'very low volume' (VLV) has been introduced for this type of herbicide application.

Two models of spinning disc VLV sprayers can now be obtained commercially and 'flowable' formulations are marketed for VLV applications. The most important technical innovation is the introduction of petroleum oil adjuvants which enable any wp or ec formulation to be applied in VLV. They also increase the foliar activity of soil active herbicides. These characteristics make VLV application of herbicides particularly suitable for hoe farmers. Future research will therefore attempt to produce VLV recommendations in addition to granular recommendations for hoe farmers crops.

Objectives of the hoe farming project

Based on the results of socio-economic research the objectives were defined as follows:

(1) To reduce the demand for hand labour during June and July in hoe farmers' mixed and sole crops.

(2) To leave no potentially harmful herbicide residues at the end of the rains.

(3) To fulfil (1) and (2) above without loss of crop yield.

(4) To devise herbicide application methods which do not increase the farmers' work-load unacceptably at any period during the season.

Socio-economic observations and formal experiments have shown that the main labour demanding operations in traditional hoe farming are

a) the first hoe weeding in cereal crops planted on the early rains with traditional minimum hoe tillage

and b) ridge splitting to prepare the land for late planted crops.

Research with granular formulations has developed the use of 'pre-plant-broadcast' applications. These are applied over the whole surface of last year's ridges and furrows before the rains start or immediately after rain but before weeds have germinated. The early cereal crops are then sown on the top of the ridge; (sowing in the furrow involves a later ridge splitting which would defeat the purpose of using a surface active herbicide). Similarly the later sown cotton and groundnuts are sown on the tops of existing ridges instead of on newly made ridges produced by ridge splitting.

Pre-plant-broadcast applications are probably the only way in which granular formulations can be used to reduce or eliminate the major early weeding operations but VLV formulations can be used much more flexibly because the high contact activity makes it possible to kill weeds which have already germinated.

Pre-plant broadcast applications are very selective because high dosages of herbicide are often actively killing germinating weeds long before the crop is sown. The activity of the original dosage is reduced considerably by the time the crop is sown and this increases crop safety.

Complete weed control is undesirable on ridges because the bare surfaces erode and the ridges need rebuilding during the peak labour period. The correct dosages applied uniformly with rather coarse granules can give a quantitative (up to 90%) reduction in weed bulk while still permitting sufficient weed cover to develop to stabilise the ridge.

Zonal testing

The composition of the weed flora on hoe farmers' land varies in response to many factors amongst which

1) Soil type
2) Zonal climate
3) Age of cultivation,
and 4) History of fertiliser application

are the most important. The early season weed flora however contains the same group of annual grasses (although in differing proportions) on all sites while the broadleaved flora also tends to contain the same group of species. The latter appear earlier and are quantitatively more important in the wetter zones. It is therefore possible to use farm centres to screen for crop tolerance and detection of weed control. It is not possible to do an economic analysis of the reduction in hoe weeding and crop response because the weed flora varies quantitatively from that on the equivalent farmer's land.

Zonal testing of diuron and norflurazon for weed control in cotton started in 1974 and the testing of linuron for the millet, sorghum, cowpea mixture started in 1975. Providing that experimental instructions are performed correctly, it should be possible to ascertain the correct dosage to be used in each centre within two or three seasons. The 'correct' dosage will be that which gives no detectable herbicide residues at harvest while giving partial and

selective weed control in June and July. The selectivity ratio will depend on the particular herbicide-crop combination but will always be well over 2:1 and will be many times this in most cases.

Socio-economic evaluation

The procedure for evaluating 'zonal dosage recommendations' in hoe farmers holdings has not yet been agreed. The great variability in weediness and farming practice make it essential that a recommendation be tested by a representative sample of hoe farmers in each zone prior to full recommendation. This process will probably have to be repeated in each zone as soon as the correct zonal dosage is determined.

Current status of investigations in the hoe farming system

Cowpeas (sole crop). Nitralin herbicide had reached the zonal testing stage but is now withdrawn by its manufacturers. Secondary screening to find other selective herbicides will be restarted.

Cotton (sole crop). Zonal testing of diuron and norflurazon has been done in 1974 and 1975. Diuron appears to be suitable for all major cotton growing areas at dosages which should be profitable.

Groundnut (sole crop). Secondary screening to replace nitralin will be necessary.

Millet-sorghum-cowpea mixture

Linuron herbicide was zonally tested in 1975. Propazine will be zonally tested, in addition, in 1976.

Important herbicides for the hoe farmer

Nitralin. This widely tested herbicide was selective in cotton, cowpeas, groundnuts and soyabeans and was the only dinitro-aniline herbicide to give good weed control when applied as a herbiliser ppb. Its abandonment by its manufacturer means that secondary testing must be repeated to find a replacement.

Manufactured granules of trifluralin gave good control in cotton in 1972 and may be a possible (but more expensive) replacement for nitralin herbiliser in the hoe farming system.

Diuron The oldest and cheapest surface active herbicide selective in cotton and sugarcane, diuron 80% wp has given excellent weed control formulated as a herbiliser applied ppb or applied VLV pre-emergent,

Diuron in oil at 1.1 units VLV pre-emergent gave 138 days of weed control at Samaru in 1975. 0.6 units gave 110 days.

Norflurazon. This new herbicide is similar to diuron but has the additional characteristics of depressing growth of established weeds when applied to the soils and being selectively active against nutgrasses (Cyperus spp). It may therefore replace diuron in wetter and heavier land areas for weed control in cotton.

Norflurazon in oil at 1.1 units VLV pre-emergent gave 116 days of measured weed control at Samaru in 1975

Atrazine This triazine herbicide is very well established for selective weed control in maize and sorghum. Pre-plant broadcast applications of manufactured granules gave consistently good weed control but these are no longer available. Herbiliser formulations ppb usually give good weed control but are not consistently reliable. VLV applications of either 50% 'flowable' commercial formulations or 80% wp + oil adjuvant give satisfactory pre-emergent weed control. Ppb applications in VLV have not been sufficiently developed but will probably be most suitable for the hoe farmer if applied to newly emerged weeds shortly after the beginning of the rains.

Linuron The only herbicide which has been definitely tolerated by millet, sorghum and cowpeas at Samaru, linuron, has a limited persistence and usually breaks down before the end of July when applied as a ppb herbiliser. This makes it particularly suitable for use in the millet-sorghum-cowpea crop mixture and allows any crop to be safely planted in the following season.

One season of zonal testing indicates that much lower dosages will be effective in the Sudan zone.

VLV application has not yet been tested.

1.6 units of linuron herbiliser ppb gave 74 days of measured weed control at Samaru in 1975

Alachlor. This herbicide is selectively active in maize, cotton, cowpeas, groundnuts and soyabean. The manufactured granules gave good weed control in cotton when applied ppb in cotton at Samaru and States sites in 1971 and 1972.

Further testing stopped when the manufacturer decided not to commercialise the product in Nigeria. It is expected to be commercially available for the 1977 cropping season and testing will

therefore recommence in 1976. This herbicide is active against Cyperus esculentus and has limited persistence.

2. General weed control in animal draught farming systems

The main value of workbull equipment to the farmer appears to be that seed beds can be quickly and efficiently prepared by ridge splitting. This is easiest on light land and may not always be possible for early crop establishment on heavy land. Workbull equipment is not fully exploited for post-emergent inter-row cultivations, farmers tend to use them primarily as earth-moving equipment to rebuild ridges after a full hoe weeding. A preliminary analysis of the crude data from the Yaba project in 1975 confirm this in a striking manner.

Table 26. Manhours used per full hoe weeding in June-July in the Yaba district, 1975

System	No. of farms	Man hours/ ha	Standard deviations
Hand hoe only	13	77.7	± 59.06
Work-bull	12	120.1	± 37.67
Diff.	–	42.4	
(Significant at P = .027			

According to table 26 a. the workbull farmers were recorded as spending more hours per hoe weeding than the farmers without workbulls. The explanation of this phenonmenon will probably emerge from the detailed analysis of the results but at least the data confirm that the farmers did not reduce their hoe weeding effort by preliminary inter-ridge moulding.

The various improved tool-bars available for sale but little used by farmers could potentially be used for precision weeding cultivations which would greatly reduce the amount of hoe weeding still required in the present system. The use of banded herbicide on the crop row combined with precision cultivation should make it possible to eliminate hoe weeding almost completely.

Objectives of the animal draught projects

"To develop cultivation systems using improved equipment combined with the use of herbicides where expedient."

It was originally believed that a granular band applicator would be needed for a workbull system using banded herbicides and a two year ITDG project at Dandawa (1972-3) had this as its main objective. So far no practicable machine suitable for workbulls has been developed but preliminary studies using pre-plant-incorporated (ppi) herbicides became possible as a result of other developments by the ITDG project.

Table 26 (b) Weed control operations now possible in workbull systems

System	Seed preparation	Herbicide use	Post emergence weed control
Ridger only	(a) Ridge splitting	-	Full hoeing f.b. moulding
Ridger + herb	(b) Ridge splitting	pre-em broadcast	Spot hoeing f.b. moulding
" " "	(c) Moulding	pre-plant broadcast	Moulding f.b. spot hoeing on 11" band.
Samcot	(d) Ridge splitting	-	Inter-ridge cult. f.b. full hoeing on 11" band.
	(e) Cultivation when required	-	Inter-ridge cult. f.b. full hoeing on 11" band.
Samcot + inc. herb.	(f) None	ppi after start of rains f.b. cult. as required	Inter-ridge cult. f.b. spot hoeing on 11" band.

The 'Samcot'

In 1974, it was found that an improved weeder attachment mounted on an Emcot ridger could be used to cultivate existing ridges immediately after the first rains. This permitted the unit to be used to prepare the seed-bed for the early sown cereals several weeks before the ridges (at Samaru) are wet enough to be split. Provided that the cultivation is done timely on light weed growth with ridges can be kept clean for cereal sowing by one or two passes with the equipment. It was also found that herbicides could be incorporated by one or two passes immediately after the start of the rains.

In 1975, a further development of mounting sowing tubes behind the weeder tines made it possible to drill crops on top or ridge by employing a second operator to feed the seed into the tube. Groundnuts, maize, cotton and sorghum were successfully established by this method.

The 'Emcot + weeder + sowing tubes' unit - 'SAMCOT' (SAMaru) developments of the EmCOT). It enables a farmer to grow crops on 30" ridges and control weeds entirely by cultivation on 19" of the furrow.

The remaining 11" band on the ridge can be controlled by full hoe weeding with a reduction of about 60% of the area at present weeded by farmers with simple ridgers. If drill sowing is not practised, variation in inter-row distance may result in crop damage when the weeder is used at this width. Development of this system will be temporarily halted during 1976 in favour of the following.

The 'Samstrad' (SAMaru development of STRADdle ridge techniques)

Another product of the ITDG project was a high clearance straddle ridge toolbar fitted with rotary cultivators. Though the prototype has design faults, it has proved possible to cultivate safely on either side of a crop row in a band only 6" wide. This not only reduces the hoe weeding by 80% but also reduces the necessary dosage proportionately when herbicide is used.

The most important potential value of the straddle row mode of cultivation is that it permits precision cultivation of individual crop rows (as opposed to the two 'half rows' affected by any inter-row operation). Variations in inter-ridge distance can be tolerated without loss of precision and each ridge can grow different crops requiring operations at different times as desired.

The introduction of a straddle-row tool-bar will therefore make it possible to develop high production techniques of mixed cropping based on alternate single rows of crops. This is predictably more productive than the maximum level of mixed cropping practicable with tractors because these have to operate on units of two or more crop rows.

Herbicide applications for workbull cultivations

Even in humid temperate zone agriculture, high volume herbicide application is being superseded by precision VLV modes of

application and there is no particular difficulty in adapting the available VLV sprayers for band application in Nigeria. Very simple dry powder applicators have been developed elsewhere and they can be adapted to apply mixtures of soil (or sand) and wettable powder herbicide formulations on the ridge. As similar units are also required to apply fertiliser in the workbull system it is likely that this mode of application will be preferred as soon as a simple and effective machine is introduced.

The use of banded pre-emergent applications will then become possible. At present it is intended to exploit pre-plant applications which can be broadcast by hand, but it is noteworthy that the farmers in the Yaba project have placed effective band applications on the ridge by hand. This development will be further examined at Yaba in 1976.

Table 27 - Potential future weed control operations in Workbull Systems

System	Seed-bed preparation	Herbicide use	Post emergence weed control
Ridger + herb (g)	Ridge splitting	Hand banded gran.pre-em	Moulding fb spot hoeing on 11" band.
Samcot + band (h)	Ridge splitting	Banded powder pre-em	Inter-ridge cult. fb spot hoeing on 11" band.
Samstrad + band applicator (i)	Cultivation during herbicide incorporation	Banded powder ppi	Straddle cult. f.b spot hoeing on 6" band
(j)	Cultivation after rain as required	Banded powder pre-em	Straddle cult. f.g. spot hoeing on 6" band

Table 27 lists the operations which are likely to be developed in the future. Operations (h), (i) and (j) await the completion of machinery development before they can be undertaken.

Banded vs broadcast incorporated herbicides

The total area cultivated by one pair of workbulls is determined by the maximum frequency with which post-emergent cultivations have to be done.

The Samcot incorporation technique used in 1975 resulted in a diffuse band of herbicide concentrated on the ridge top with traces of herbicide in the ridge shoulders and the furrows. The effect of

the latter was to increase the cultivation interval from nineteen days in the checks to twenty nine days in the best herbicide treatments. This demonstrates how the total area cultivated by one pair could be increased by low dosages of broadcast incorporated herbicide.

Important herbicides for the workbull farmer

All the surface active herbicides suitable for the hoe farmer can also be used by the workbull farmer. In addition the following incorporated herbicides can be used pre-plant.

Trifluralin. Selective in cotton, groundnuts and grain legumes.

The 5% manufactured granular formulation incorporated 13 days pre-plant to June sown cotton, gave 115 days weed control at Samaru in 1975. The ec formulation is now being imported. This formulation is widely used in USA for the local preparation of herbilisers. The importer is intending to import equipment developed for this purpose. It is proposed to import pilot quantities of the 5% granular formulation to enable comparative economic tests of the three formulations to be made.

Dinitramine. Selective in cotton, groundnuts and grain legumes.

This is generally similar to trifluralin but requires a lower dosage and is less volatile. An experimental 2% granular formulation incorporated 13 days pre-plant in June sown cotton at 1.6 units gave 87 days measured weed control at Samaru in 1975. 0.8 units of the same formulation incorporated 53 days pre-plant in groundnuts, gave complete pre-plant weed control and 100 days of measured weed control after planting.

The ec formulation is on sale in Kano.

Vernolate: Selective in groundnuts

It is primarily of interest for its activity against *Cyperus esculentus* but is also a valuable rotation herbicide to trifluralin. 1.6 units of the ec formulation incorporated as herbiliser 53 days pre-plant gave some pre-plant weed control and 21 days measured weed control at Samaru in 1975. It persisted for 76 days but did not control all weed species during this period.

Butylate: Selective in maize.

This gives general weed control and is also active against *Striga sp* and *Cyperus sp*.

3.2 units of the 10% granular formulation incorporated 7 days pre-plant gave 26 days measured weed control. 6.4 units incorporated 70 days pre-plant gave complete pre-plant weed control, 17 days post-

plant measured weed control and a large yield increase attributable to striga control.

Method of applying herbicide

A big drawback to the successful extension of spray regime has been the need for large volumes of water. Farmers are not willing to carry some 225 litres ha^{-1} of water, weighing some 230 kgs. It is partly because of this that low volume and ultra low volume machines have been developed. However, where soil applied herbicides, applied before or at sowing, are used and it is also intended to apply fertiliser, it may be possible to apply the herbicide in two stages. First to the fertiliser, coating the fertiliser with herbicide, and then applying the "herbiliser". In the experiments described below, this was done to both cotton and maize in 1975.

a) Herbiliser applied to cotton

There were eight treatments to cotton grown in four replication of a randomised blocks design. These were:

1. No herbicide; 100 kg. ha^{-1} boronated superphosphate broadcast
2. 2.0 kg. a.i. ha^{-1} Diuron Sprayed with knapsack sprayer
3. 3.0 " " " " " " " "
4. 4.0 " " " " " " " "
5. 2.0 " " " " applied on and with boronated superphosphate
6. 3.0 " " " " applied on and with boronated superphosphate
7. 4.0 " " " " applied on and with boronated superphosphate
8. No herbicide; 100 kg. ha^{-1} boronated superphosphate placed.

Results are given in Table 28.

Table 28

Total cotton dry matter, yield, and weed dry matter as kg ha^{-1}

Treatment	Seed cotton	Cotton din	Weed weight
1	297	3106	4728
2	872	4344	4449
3	891	4237	3077
4	916	4329	7769
5	711	3716	4499
6	874	4214	3790
7	795	3894	4045
8	324	3158	6559
s.e. diff.	± 31.2	± 152.2	± 90.5

All herbicides, whether sprayed or applied as herbicide significantly increased seed cotton yield, but had little effect on total dry matter.

The experiment is being repeated but it is clear that "herbiliser" application to cotton shows promise.

b) The second trial compared the same treatments, though using a different herbicide, to maize. The experiment design was the same. Treatments were:

1. No herbicide; 100 kg. ha^{-1} single superphosphate broadcast
2. 2.0 kg. a.i. ha^{-1} Atrazine sprayed with knapsack sprayer
3. 3.0 " " " " " " " "
4. 4.0 " " " " " " " "
5. 2.0 kg ai ha^{-1} Atrazine broadcast as herbiliser
6. 3.0 " " " " " "
7. 4.0 " " " " " "
8. No herbicide; 100 kg ha^{-1} single superphosphate placed.

Maize grain yield and weed dry matter ha^{-1} are given in Table 29.

Table 29

Maize Grain yield and Weed dry matter in kg.ha^{-1}

Treatment	Maize grain	Weed wt.
1	313	3379
2	501	3640
3	836	3111
4	957	2784
5	736	3540
6	675	3622
7	618	3475
8	158	4371

Although herbicides, either sprayed or on fertiliser, gave grain yield responses, yields were too poor to attribute a firm conclusion. This experiment was done at University farm, known to produce poor maize yields, and is sited at Samaru in 1976.

Weed Control in Irrigated Areas (1975-76 results)

1. Screening of herbicides for the control of Cyperus spp. and other weeds in maize*

The herbicides were tested at four locations. Results from Samaru are reported in table 30, while those from Kadawa and Maiduguri trials are given in table 32. Practically no grain yield was obtained at Ganawuri and the data from that site are not presented here.

SAMARU:

The site was infested with Cyperus esculentus and annual grasses with little Cyperus rotundus present. Both rates of butylate + atrazine and alachlor + atrazine controlled Cyperus esculentus and annual grasses (table 30). Alachlor combinations, however, were not effective on C. rotundus.

In the same experiment, atrazine applied post-emergence to maize (with Sun oil 11E) after pre-plant application of butylate gave significantly better weed control than when applied, tank mixed, with butylate, pre-sowing. This could be due to:

a) control of those weeds which escaped pre-sowing application of herbicides,

and b) longer duration of control (post-emergence application done four weeks later than pre-plant application).

The difference in the total weed weight was small, however, and may not justify an extra operation. In very weedy situations this may prove beneficial but the weeds must be very young. Glyphosate treatments, as usual, gave good control of Cyperus spp. but failed to control annual grasses. The application of the chemical had to be delayed due to droughty conditions in early June with the result that the weeds were older and less susceptible to the chemical.

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* All rates of herbicides given in the text and tables are in kg (active) per hectare.

Terminology used:

Pre-em. (Pre-emergence): After sowing but before germination of the crop.

Post-em (Post-emergence): After the germination of crop

PPI (Pre-plant incorporated): Before sowing the crop and mixing with the soil immediately.

PPWF (Pre-plant on weed foliage): Weeds allowed to grow and herbicide applied on the foliage of these weeds.

Table 30. Effect of herbicides applied in maize on Cyperus and Total Weed Weights, Maize Grain and TDM in kg/ha at Samaru

Treatment	Cyperus spp	Logarithm[2]	Total weeds	Logarithm[2]	Grain	T D M
1. Alachlor at 2 + atrazine at 1 pre-em	52.6	0.908 c	261	1.41 b	6361 ab	12695 a
2. " 3 + " 1.5 "	35.1	0.602 bc	182	1.21 ab	7065 ab	13769 a
3. Butylate at 4 + " at 2 ppi	11.7	0.288 ab	354	1.46 b	6722 ab	12463 a
4. " 6 + " 2 "	26.4	0.357 ab	306	1.45 b	6435 ab	12491 a
5. " at 4 ppi + atrazine at 2 post-em[1]	6.9	0.242 ab	95	0.95 a	6593 ab	12917 a
6. " 6 " + " 2 "	4.2	0.165 ab	172	0.98 a	7324 a	13667 a
7. Glyphosate at 2 ppwf + atrazine at 2 post-em[1]	9.1	0.273 ab	1073	2.00 c	4963 cd	8380 c
8. " 3 " + " 2 "	2.2	0.095 a	1491	2.08 c	4565 d	8528 c
9. Hand weeded (twice)	222.0	1.441 d	1044	2.02 c	5880 bc	10667 b
S.E.		0.139		0.13	405	600

1. Applied with Sun Oil 11E at the rate of 10 l/ha
2. Cyperus and total weed weights from sampled area transformed to logarithms $x = \log_{10}(x + 1)$ and $x = \log_{10} x$, respectively for analysis.

Data in the same column followed by a common letter are not significantly different at the 5% level.

The total dry matter yield in case of alachlor and butylate treatments was significantly higher than the handweeded check but the grain yield was significant in case of butylate at 6 kg/ha + atrazine 2 kg/ha post-emergence, only. On the other hand, glyphosate treatment resulted in lower yield than hand weeding. This was probably due to smothering by thick weed cover at sowing and late weed competition. Slight toxicity from the herbicide cannot be ruled out.

Study of the residual effects: The plots at Samaru were cultivated after harvesting maize. Tomatoes Roma and Wheat Indus 66 were sown to see the residual effects of herbicides applied to maize. No toxic symptoms were observed in any of the crops. This was supported by yields obtained in various treatments (table 31).

Table 31. Residual effects of herbicides on total and marketable tomatoes (Tons/ha), and grain and total dry matter yield of wheat (kg/ha)

Treatment	Tomatoes		Wheat	
	Total	Marketable	Grain	T D M
1. Alachlor at 2 + atrazine at 1 pre-em	57.7	53.1	1079	4063
2. Alachlor at 3 + atrazine at 1.5 pre-em.	53.1	50.3	1008	4584
3. Butylate at 4 + atrazine at 2 ppi.	65.1	61.2	1223	4480
4. Butylate at 6 + atrazine at 2 ppi	54.8	49.2	1274	4584
5. Butylate at 4 ppi + atrazine at 2 post-em.	62.9	55.2	1100	4792
6. Butylate at 6 ppi + atrazine at 2 post-em.	51.7	46.7	1140	4688
7. Glyphosate at 2 ppwf + atrazine at 2 post-em.	57.9	53.9	1181	4792
8. Glyphosate at 3 ppwf atrazine at 2 post-em.	59.2	54.3	1649	5521
9. Hand weeded (twice)	57.1	52.8	1091	4480
S.E.	6.5	6.8	208	458

KADAWA

At this site Cyperus esculentus and Cyperus tuberosus were present in addition to annual weeds. Alachlor + atrazine and butylate + atrazine gave a good control of C. esculentus and annual weeds and the maize yields were comparable with hand weeding twice (table 32), although alachlor was comparatively less effective on C. tuberosus.

At this location perfluidone (MBR-8251) was also tried. This chemical is effective for the control of Cyperus spp. but is not selective in maize. It was observed that maize tolerated the chemical at 2 kg/ha. when the maize seeds were treated with 1,8 Napthalic anhydride, and the grain yield was not significantly different than hand weeding. At 4 kg/ha, however, maize was injured severely.

MAIDUGURI

The site was infested with annual weeds only. Here atrazine proved to be the best herbicide giving excellent weed control with higher crop yield.

Atrazine and its combinations with alachlor and butylate are now proposed to be tested at State locations whereas work with glyphosate etc. will be continued at IAR sites at Samaru/Kadawa.

2. Effect of plant populations x spacings of maize on the growth of Cyperus spp. and other weeds

Maize cv NCA was sown in all combinations of 37,62 and 93 thousand plants/ha with row spacings of 45,60 and 90 cm. The experimental area received a blanket application of 6 kg of butylate and 2 kg of cyanazine, applied pre-sowing and incorporated with a tractor drawn spring tooth harrow.

There was little regrowth of C. esculentus (the only Cyperus sp. present) in the presence of butylate. It was observed, however, that the regrowth at the highest population was significantly lower than the lowest population (table 33). Further, there were significant differences in the total weed weights which were lower at high populations and narrow ros spacing.

The total dry matter of maize was significantly higher at medium and high populations as compared to low population of 37,000/ha while 45 cm spacing was better than 60 and 90 cm spacings.

Grain yield of maize increased from lower to medium population and then decreased. No significant differences were observed in row spacings although there was a decreasing trend from narrow to wider spacing. Looking at the interactions, it can be seen that there were

Table 32. Effect of Herbicides applied in maize on Grain and TDM yield in Kg/ha.

Treatment	Kadawa				Maiduguri			
	Grain		TDM		Grain		TDM	
1. Alachlor at 2 + atrazine at 1 pre-em.	3695	a	7927	ab	833	b	11482	abc
2. " " 3 + " " 1.5 "	3695	a	8218	ab	1241	ab	11259	abc
3. Butylate at 4 ppi + atrazine at 1 pre-em.	3610	a	8745	a	944	b	10926	abc
4. " " 6 " + " " 1.5 pre-em	3567	a	[illegible]	a	1111	ab	10167	bc
5. Perfluidone at 2 pre-em[1]	3440	a	7400	ab				
6. " " 4 "	807	b	3700	c				
7. Atrazine at 2 pre-em.					1537	a	14241	ab
8. " " 4 "					1611	a	14685	a
9. Hand weeded (twice)	3780	a	7961	ab	1296	ab	10407	bc
10. Unweeded	1997	b	5382	bc	796	b	8741	c
S.E.	404		862		175		1306	

Data in the same column followed by a common letter are not significantly different at the 5% level.

1. Seed treated with 1,8 Napthalic anhydride.

Table 33. Effect of maize populations x spacings on *Cyperus* and Total Weed Weights, Maize Grain and TDM in Kg/ha

Treatments	*Cyperus sp.*	Logarithm[1]	Total Weeds	Logarithm[1]	Grain	T D M
37,000 plants ha^{-1}	8.6	0.321 b	1,072	2.203 c	6039 b	12006 b
61,700 " "	4.1	0.202 ab	371	1.685 b	6811 a	13940 a
92,600 " "	3.3	0.174 a	225	1.226 a	6132 b	13179 a
S.E.		0.043		0.099	166	313
45 cm row spacing	5.0	0.215	424	1.480 a	6584	13693 a
60 " " "	5.2	0.251	576	1.732 ab	6204	12695 b
90 " " "	5.8	0.232	669	1.903 b	6193	12726 b
S.E.		0.043		0.099	166	313
37,000 plants $ha.^{-1}$ at 45 cm space	9.0	0.315	921	2.136	6389 ab	12683
" " " 60 " "	5.4	0.259	1,188	2.244	5525 bc	11219
" " " 90 " "	11.4	0.389	1,108	2.230	6214 abc	12101
61,700 " " 45 " "	3.2	0.168	299	1.462	6821 a	14601
" " " 60 " "	4.3	0.222	379	1.761	6615 a	13495
" " " 90 " "	4.3	0.217	436	1.832	6996 a	13734
92,600 " " 45 " "	2.8	0.161	50	0.841	6553 a	13799
" " " 60 " "	5.8	0.272	160	1.190	6471 a	13382
" " " 90 " "	1.4	0.090	464	1.646	5370 c	12348
S.E.		0.074		0.172	287	542

Data in the same column followed by a common letter are not significantly different at the 5% level.

1. Sample plot weights transformed to logarithm $x = \text{Log}_{10}(x + 1)$ and $x = \text{Log}_{10}\ x$ for *Cyperus* and total weeds, respectively, for analysis.

no significant differences between the three row spacings at the lower and medium populations but 90 cm row spacing at a population of 93 thousand/ha caused a significant reduction in grain yield as compared to narrow and medium row spacings. Obviously, the competition within the row was more which resulted in lower grain yield.

There was a clear indication that moderately high populations grown on narrow to medium row spacing will not only yield better but also suppress the later growth of the weeds which is important for further spread of weeds like Cyperus spp.

3. Screening of herbicides for the control of Cyperus spp. and other weeds in groundnuts:

Vernolate, alachlor, perfluidone and benfluralin + Gulf S 21634 were compared with two hand weedings in a preliminary trial in groundnuts cv F 439.4.

All herbicidal treatments had lower weights of C. esculentus as compared to hand weeded check (table 34), although alachlor at 1.5 kg/ha and S 21634 combination at 1.5 + 1 kg/ha were somewhat inferior to others.

As regards other weeds, alachlor was the only chemical which gave an appreciable control of Paspalum orbiculare. This encouraged the growth of broad leaved weeds which were also more in hand weeded plots. All other herbicides were not effective in controlling this annual grass.

Pod yield of groundnuts, which was poor on the whole, in case of alachlor was comparable with hand weeded check plots. All others were lower than the check and were influenced by the degree of weed control offered by a treatment except in case of perfluidone where the crop seems to have suffered from herbicide toxicity inspite of the fact that the seed was treated with 1,8 Napthalic anhydride.

4. Testing of herbicides for the control of Cyperus spp. and other weeds in cotton:

Perfluidone and glyphosate, the two promising herbicides from 1974 trial, were compared with some others. The experimental area was mainly infested with C. esculentus, Paspalum orbiculare, Eleusine indica, Portulaca oleracea, Amaranthus sp., Blumea sp. and Vernonia sp. There were a few patches of C. rotundus.

Perfluidone treatments, at both rates, resulted in good Cyperus control with seed cotton yields comparable to hand weeded check (table 35).

Table 34. Effect of herbicides on C. esculentus and Total Weed Weights and Pod Yield of G. Nuts in Kg./ha

Treatment	C. esculentus	Logarithm	Total Weeds	G. Nut Pods
1. Vernolate at 1.5 ppi	8.8	0.505	3284	440
2. " " 3.0 "	6.6	0.474	3019	457 a
3. " " 6.0 "	19.1	0.719	2744	480 a
4. Alachlor " 1.5 pre-em	37.8	1.114	1477 a	695 a
5. " " 3.0 "	6.3	0.334	2035	737 a
6. " " 6.0 "	5.0	0.373	1508 a	860 a
7. Perfluidone at 1.5 pre-em.	4.1	0.358	4277	169
8. " " 3.0 "	5.6	0.413	2227	243
9. " " 6.0 "	13.8	0.612	2017	198
10. Benfluralin " 1.5 ppi + S 21634 at 1 post-em	24.4	0.848	2049	546 a
11. " " " " + " " 2 "	0	0	2447	482 a
12. " " " " + " " 4 "	0.6	0.068	3351	417
13. Hand weeded (twice)	175	5.234	1384	711
S.E.		0.150	154	114
Lsd 5% (C vs T)		0.359	362	268
(T vs T)		0.440	444	329

a - Do not differ from check (Hand weeded) at the 5% level of significance. All other figures in the same column are significantly different.

Portulaca sp. was consistently present at both rates while annual grasses emerged at a later stage, mostly at the lower rate.

Norflurazone was not as effective on C. rotundus (which started to appear in 4-5 weeks time) but gave a better control of Portulaca sp. especially at the higher rate. There was a visible stunting of the crop at the higher rate in the beginning, which disappeared later, and may be the cause of slightly lower yield at the higher rate.

Glyphosate gave an excellent control of weeds in the beginning but the plots got heavily reinfested with annual weeds (mostly broad leaved) within 4-5 weeks. These weeds at the time of spraying post-emergence glyphosate were as high as the crop with the result that the crop also received the herbicide on its upper leaves and was thus severely injured.

MSMA post-emergence was tolerated by the crop but the weeds must have done considerable damage before they were killed. Thus the crop yield was reduced. Diuron in oil applied 6 weeks after glyphosate application was also not very effective in controlling these weeds.

Table 35. Effect of herbicides on the weed control and seed cotton yield of cotton:

Treatment	Weed Cover Rating [1]	Estimated Seed/Cotton kg/ha
1. Perfluidone at 3 kg. pre-em	3.25	1544
2. " " 4 "	2.25	1685
3. Norflurazone " 1 "	3.75	1596
4. " " 2 "	1.75	1434
5. Glyphosate at 2 kg ppwf + 1 kg post-em	3.25	741
6. " " " " + 2 " "	1.50	602
7. " " " " + MSMA at 2 kg post-em	3.50	1320
8. Glyphosate at 2 kg ppwf + Diuron-in-oil at 0.25 kg post-em	7.00	1368
9. Diuron 1.6 kg pre-em + S 21634 at 1 kg post-em	3.50	1288
10. Diuron at 1.6 kg pre-em + S 21634 at 2 kg. post-em	3.25	1307
11. Diuron at 1.6 kg. pre-em. + S 21634 at 4 kg. post-em	2.75	1561
12. Hand weeded (twice)	1.00	52

1. Rating 0--9; 0 = no weeds, 9 = full weed cover. Scored at the end of the season.

Pre-emergence diuron gave a good weed control but the Cyperus spp. were not affected. The chemical was not as persistent as other residual herbicides in this experiment with the result that annual grasses started to appear late in the season. S 21634 applied post-emergence killed C. esculentus at all rates while C. rotundus regenerated at the lowest rate. It was not effective on other weeds.

Perfluidone and Norflurazone are now proposed to be tested at State locations, while others will continue to be tested at IAR Samaru/Kadawa.

Study of the residual effects:
Tomatoes:

Weeds from one of the cotton ridges were cleaned with hoe and tomatoes cv Roma were transplanted in the beginning of December 1975 (immediately after first picking of cotton). The ridges were slightly remoulded and the tomatoes were transplanted on the shoulders of ridges in the middle of cotton plants. Tomatoes were fertilized at rate of 200 kg/ha of super phosphate + 160 kg/ha of nitrochalk placed 2 weeks after transplanting and another 120 kg/ha nitrochalk 4 weeks later.

Cotton and tomatoes remained together in the field for more than 4 weeks when cotton frames were removed after its final picking was over. By that time some of the tomato plants had started flowering. The cotton plants protected the young tomatoes from the desiccating effect of wind while weekly irrigation applied to tomatoes had no adverse effect on the boll opening of cotton. The cotton plants had sprouted again at the time of their removal.

Perfluidone at both rates and glyphosate + diuron in oil treatments looked a bit stunted in the beginning while others looked quite well except two plants in one of the norflurazone plots at 2 kg, which showed toxicity symptoms. Fruit yield of tomatoes (table 36) indicate that perfluidone residues depressed yields while the presence of norflurazone (if any) was tolerated. One other treatment which gave a poor yield was glyphosate followed by diuron in oil. This treatment became very weedy in the latter part of cotton crop and therefore might have suffered from nutritional deficiency. The rate of diuron used was so low that there was little likelihood of any damage from its residues.

Sorghum

Sorghum Waga white was sown in January 1976 on one of the other two ridges, after the removal of cotton and completely re-building it. The crop was harvested for its dry matter determination in April and was not taken to maturity due to anticipated bird damage. Sorghum plants in plots receiving norflurazone at 2 kg in the previous wet season showed symptoms of injury but recovered soon and there seems to be no effect on the final yield (table 36). All other herbicides were also safe for this crop.

Table 36. Residual effects of herbicides applied in cotton (wet season, 1975) on tomatoes and sorghum in the following dry season.

Treatment	Tomato fruits (Tons ha)		Sorghum DM (Tons ha)
	Marketable	Total	
1. Perfluidone at 3 kg pre-em	53.3	58.5	4.8 a
2. " " 4 " "	51.8	55.9	4.9 a
3. Norflurazone " 1 " "	67.9 a	72.8 a	3.7 a
4. " " 2 " "	63.7 a	69.0 a	3.8 a
5. Glyphosate at 2 kg ppwf + 1 kg post-em.	62.3	68.3 a	3.4 a
6. Glyphosate at 2 kg ppwf + 2 kg post-em.	73.6 a	78.1 a	3.6 a
7. Glyphosate at 2 kg ppwf + MSMA at 2 kg post-em.	76.1 a	81.1 a	3.3 a
8. Glyphosate at 2 kg ppwf + Diuron (in oil) at 0.25 kg post-em.	51.5	57.6	3.4 a
9. Diuron at 1.6 kg pre-em + S 21634 at 1 kg post-em	67.1 a	72.4 a	4.0 a
10. Diuron at 1.6 kg pre-em + S 21634 at 2 kg post-em.	64.7 a	71.4 a	3.5 a
11. Diuron at 1.6 kg pre-em + S 21634 at 4 kg post-em	64.3 a	70.3 a	3.7 a
12. Hand weed (check)	78.5 a	83.6 a	3.7 a
S.E.	5.4	5.9	0.7

Yield figures in the same column denoted by a common letter do not differ significantly from check. Others differ significantly at 5 % level.

5. Residual effects of herbicides applied in cotton in wet season 1974:

The object was to see any residual effects of herbicides on the weed population (C. rotundus) and the crops that follow cotton in the next wet season. The experimental plots were sampled in May 1975 to count the number of Cyperus tubers with a 10 cm diameter auger up to a depth of 30 cm. The number of C. rotundus plants were

counted once before disking the soil for sowing test crops and then 4 weeks after disking. The test crops were sorghum cv Naga White, tomatoes cv Roma and groundnuts cv. F439.4. Tomatoes were harvested after 8 weeks of transplanting while the other two crops were harvested after 11 weeks of sowing for TDM determination. All plots were weeded after taking the second count of C. rotundus.

None of the test crops showed any signs of injury (table 37). Repeated application of glyphosate lowered the number of Cyperus plants in the following season also, and sometimes increased the crop yield.

6. Efficient use of glyphosate for the control of Cyperus spp.

It was observed in 1974 that glyphosate not only gave seasonal control of Cyperus spp. but also reduced its population in the following year. The experiment was designed to see whether ammonium sulphate tank mixed with glyphosate can increase its toxic action and whether application of fertilizer to the Cyperus spp. to help it grow luxuriantly will make it more susceptible to glyphosate.

Three rates of glyphosate - 1, 2 and 4 kg (G treatments), three rates of ammonium sulphate - 0, 5 and 10 kg/ha (S treatments) and three rates of nitrogenous fertilizer at the start of the experiment - 0, 25 and 50 kg. N/ha (N treatments) were tried in a 3^3 factorial experiment with higher order interaction confounded. Maize variety Upper Volta Early was used.

It was the intention to apply glyphosate 4 weeks after application of N treatments but could not be done due to droughty conditions caused by lack of rain in early June (the weeds started to show signs of wilting). By the time the rains resumed and the weeds started to grow actively, some of them had already made a rank growth with the result that the herbicide was not very effective on them. Also they smothered the germinating maize plants and provided opportunity to rodents to hide and damage maize. The results are given in table 38.

A rapid kill of Cyperus spp. was observed with higher rates of glyphosate and with increasing rate of nitrogen application in the beginning of the experiment. However, there was no difference in the Cyperus population in the following year whether nitrogen was applied or not. Glyphosate rates showed a little difference.

Table 37. Residual effects of herbicides applied in cotton (1974) on the number of Cyperus tubers and plants/sq.m. and TDM yield of sorghum, tomatoes and groundnuts in kg/ha.

Treatment	Cyperus tubers May 75[1]	Cyperus plants June 75[1]	Sorghum TDM	Tomatoes TDM	G.Nuts TDM	Cyperus plants July 75
1. Glyphosate at 4 ppwf	534 bc	310 bc	1942 abc	1153 ab	907	979 c
2. " " " " + 1 post-em	466 a	90 a	1801 abc	930 bc	1053	615 a
3. " " " " + 2 "	645 ab	67 a	2471 a	1468 a	1240	637 a
4. " " " " + MSMA 2 post-em	797 abc	180 ab	2211 ab	857 bcd	1153	662 ab
5. Tetrapion at 2 pre-em	450 a	411 cd	1664 abc	702 bcd	1039	944 c
6. " " 4 "	619 ab	166 ab	1956 abc	378 d	839	1090 c
7. Perfluidone at 1.5 pre-em.	1272 c	750 e	1504 abc	433 cd	825	1413 d
8. " " 3.0 "	882 abc	709 e	1213 bc	666 bcd	1062	929 bc
9. " " 4.5 "	600 ab	445 cd	1021 c	424 cd	980	860 abc
10. Check (Hand weeded)	1043 bc	615 de	998 c	766 bcd	1153	991 c
S.E.			307	165	174	87

Data in the same column followed by a common letter are not significantly different at the 5% level.

1. Analysis done on transformed data.

Table 38. Effect of Glyphosate x Ammonium Sulphate x Nitrogen Fertilizer on the Control of *Cyperus* spp.

A. Cyperus Control Rating (4 weeks after application):

i. G x S:

Gly \ A/S	S_0	S_1	S_2	Glyphosate average
G_0	2.40 a	2.23 ab	2.07 ab	2.23 a
G_1	1.73 cd	1.93 bc	2.19 ab	1.95 b
G_2	1.64 cd	1.57 d	1.55 d	1.59 c
Am. sul. average	1.92	1.91	1.94	

ii. S x N:

Am. sul. \ N	N_0	N_1	N_2	Am. Sul. average
S_0	2.24	1.95	1.59	1.92
S_1	2.19	1.88	1.66	1.91
S_2	1.97	2.06	1.77	1.94
Nitrogen average	2.14 a	1.96 a	1.67 b	

iii. G x N:

Glyphosate \ N	N_0	N_1	N_2	Glyphosate average
G_0	2.32 a	2.20 ab	2.1[illegible] ab	2.23 a
G_1	2.23 a	2.12 ab	1.50 d	1.95 b
G_2	1.86 bc	1.57 cd	1.33 d	1.59 c
Nitrogen average	2.14 a	1.96 a	1.67 b	

S (G, S, N) = 0.06
(G x S, S x N, G x N) = 0.11

Rating : 0—9 Where 0 = full control, 9 = no effect.
Data transformed to square roots for analysis. Figures followed by a common letter do not differ at 5% level of significance.

Table 38/contd.

B. Number of Cyperus Plants/(sq.m.) in the Following Year

i. G x S:

Glyphosate \ A/S	S_0	S_1	S_2	Glyphosate average
G_0	316	262	280	286
G_1	214	265	210	230
G_2	226	225	240	231
Ammonium sulphate average	252	251	243	

ii. S x N:

Amm. sul. \ N	N_0	N_1	N_2	Ammonium sul. average
S_0	280	236	240	252
S_1	291	249	211	251
S_2	187	255	288	243
Nitrogen average	253	247	246	

iii. G x N:

Glyphosate \ N	N_0	N_1	N_2	Glyphosate average
G_0	328	274	256	286
G_1	224	216	248	230
G_2	207	249	235	231
Nitrogen average	253	247	246	

S.E. (G, S, N) = 53
(G x S, S x N, G x N) = 92

Table 38/contd.

C. Maize Total Dry Matter in Kg. ha.$^{-1}$

i. G x S:

Glyphosate \ A/S	S_0	S_1	S_2	Glyphosate average
G_0	3057	2944	2824	2941 b
G_1	3465	3412	3740	3539 a
G_2	2911	3530	2417	2953 b
Ammonium sulphate average	3144	3295	2994	

ii. S x N:

A/S \ N	N_0	N_1	N_2	Ammonium sul. average
S_0	3669 ab	3162 abc	2602 c	3144
S_1	2949 abc	3021 abc	3916 a	3275
S_2	3702 ab	2762 bc	2517 c	2994
Nitrogen average	3440	2982	3012	

iii. G x N:

Glyphosate \ N	N_0	N_1	N_2	Glyphosate average
G_0	3204	2724	2897	2941 b
G_1	3804	3391	3416	3539 a
G_2	3312	2830	2716	2953 b
Nitrogen average	3440	2982	3012	

S.E. (G, S, N) = 185
(G x S, S x N, G x N) = 312

Figures followed by a common letter do not differ at 5% level of significance.

Total dry matter yield of maize was reduced with highest and lowest rates of glyphosate which could be due to poor weed control at the lowest rate and crop toxicity at the highest rate.

7. Control of Cyperus rotundus and other weeds in Wheat:

Triallate, chlortoluron, diuron, fluorodifen, perfluidone, mecoprop, 2,4-D Na and dicamba + OCS 21944 were tried in Wheat Indus 66. The experimental plot was at a lonely place and was thus attacked by rodents which continued to eat young wheat plants inspite of putting baits. The attack was so serious that very few wheat plants reached maturity.

Mecoprop at 1.6 and 3.2 kg, 2,4-D Na at 1.2 and 2.4 kg and triallate at 2.4 and 4.8 kg gave moderate to good control of Cyperus rotundus but triallate injured wheat at both rates. Other herbicides tried did not control Cyperus rotundus but gave a moderate control of other weeds present. Mecoprop and 2,4-D Na were not effective on annual grasses.

8. Dry Season Cultivation for the Control of Cyperus rotundus:

Mould board plough, disc plough, chisel plough and rotavator with underbuster were used to cultivate the soil to see the effect on the desiccation and subsequent sprouting of Cyperus rotundus in the wet season. All implements were used once only in the beginning of dry season 1975-76 except the chisel plough which was repeated in March 76. The proposed depth for cultivation was 22 cm which could be achieved in case of mould-board and chisel ploughs only. Disc plough could penetrate to 12 cm and the rotavator 10 cm deep only. Counts of Cyperus rotundus plants were taken before cultivation and at the beginning of wet season and are given in table 39.

One mould board ploughing reduced the Cyperus rotundus infestation by 70% of the check and was also significantly better than other implements used in the study. It appears, however, that follow up cultivations would reduce the infestation further.

Chisel ploughing was not as effective as the use of mould-board inspite of the fact that it also reached the proper depth. The implement has the disadvantage that it leaves the soil

between chisels undisturbed. Better results can be achieved

Table 39. Number of C. rotundus plants/sq., m. before and after dry season cultivation

Treatment	Before cultivation		Next Wet Season	
	Number	% of Check	Number	% of Check
1. Mouldboard plough (once)	1414	100	160 a	30
2. Disc plough (once)	1449	103	388 c	72
3. Chisel plough (twice)	1385	98	287 b	53
4. Rotavator with under-buster (once)	1553	110	303 b	56
5. Check (uncultivated)	1413	100	537 d	100
S.E.	69		27	

Figures followed by a common letter in the same column do not differ at 5% level of significance.

with disc plough and rotavator if they are used when the soil has some moisture and their penetration is proper.

It was observed that dry season cultivation had no effect on Cyperus esculentus. On the other hand its population was a bit increased and the growth was more vigorous where the competition from C. rotundus was reduced.