CRIMSON CLOVER-COTTON RELAY CROPPING WITH CONSERVATION TILLAGE SYSTEM

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Abstract. In research trials, 'Relay-Cropping System' of two cover crops with conservation tillage was compared with a conventional production system for cotton using all recommended practices, during 1991-92 and 1992-93. Three cover crops: Crimson clover (*Trifolium incarnatum* L.`Dixie'), subterranean clover (*Trifolium subterraneum* L. 'Mt. Barker'), and rye (*Secale cereale* L. 'Wrens Abruzzi') were planted in November, 1991 and again in November, 1992. Crimson clover and subterranean clover plots were strip-killed with glyphosate (Roundup) in mid-April and then planted no-till in dead strips, two weeks later. For conventional production, rye plots were harrowed and deep-turned with moldboard plow. Cotton (*Gossipium hirsutum* L.) was planted with modified no-till John Deere 71 planters. No fertilizers or insecticides were applied to no-till 'Relay Cropping System' plots with crimson and subterranean clover. Relay plots produced significantly higher yields than conventional plots during both years.

A grower field of 7.2 acres was planted with 'Dixie' crimson clover in Fall, 1993. Clover has re-seeded every year since then. Five crops of cotton were raised from 1994 to 1998. Cotton was strip-till planted for first four years and 1998, it was planted with a no-till planter. No insecticides were used for producing these five crops. Only starter solution and nitrogen fertilizers were used during first four years and in addition, sulfate of potash-magnesia was also applied in 1998. In spite of substantial reduction in inputs this non-irrigated field produced cotton yields above the state average during all five years. Thus, 'Relay-Cropping System' which is environmentally friendly, socially acceptable, and economically feasible offers an alternative production system to a conventional production system.

INTRODUCTION

Increasing concerns about environment and farm profitability led scientist to research alternative systems which are less reliant on off-farm chemical inputs. Many sustainable crop production systems with emphasis on 'Total System' have been researched for a variety of vegetable and field crops (Brunson, 1991, Phatak, 1992, 1994, 1998). Conservation tillage and cover crops were key components in all these alternative systems. Two major barriers to adaptation of the alternative systems have been decreased yields and specific pest problems. Yield reduction made many alternative systems less attractive for most crops. A prime crop example having specific problem was boll weevil in cotton production in the southeastern United States.

The Georgia Boll Weevil Eradication Program (BWEP) was initiated in 1987 with boll weevil population severely depressed by 1990 (Lambert, 1991). By 1992, boll weevil was essentially eradicated in Georgia. The success of BWEP dramatically reduced the total number of insecticide sprays required for cotton production. Encouraged by the success of the BWEP, researchers and cotton producers diverted their interests towards evaluating alternative systems to further reduce off-farm pesticide and fertilizer inputs. Researchers and growers had been studying alternative systems which reduced tillage, fertilizer and pesticide inputs (Phatak, 1992, 1994; Leidner, 1994; Bugg et al., 1991; Phatak et al., 1991; Yancy, 1994, 1996). Information from on-going research on sustainable production of vegetable and agronomic crops with cover crops, reduced tillage, reduced fertilizers and reduced pesticides was useful in developing alternative production strategies for cotton production. Strategies for 'Relay-Cropping System' has been outlined (Bugg et al., 1991; Phatak ,1993). Thus, research was conducted to evaluate relay-cropping with conservation tillage and cover crops for cotton production in 1991-92 and 1992-93. A number of field plots were established in Fall, 1993, after successful completion of 'No-Till Relay System' research. This paper presents results of research trials and data from a grower's field plot that has been in cotton production for five years with the 'Crimson Clover-Cotton Relay System.' In this paper more emphasis is placed on soil fertility, nutrient management, and recycling.

MATERIALS AND METHODS

Research Trials

'No-Till Relay System' with crimson and subterranean clovers was compared with conventional tillage system with rye cover crop. Field studies were conducted during 1991-92 and 1992-93 at the Horticulture farm, at the

Coastal Plain Experiment Station, College of Agricultural and Environmental Sciences, University of Georgia, Tifton. Three cover crops: Crimson clover (*Trifolium incarnatum* L.`Dixie'), subterranean clover (*Trifolium subterraneum* L. 'Mt. Barker'), and rye (*Secale cereale* L. 'Wrens Abruzzi') were planted in November, 1991 and again in November, 1992. Plots were 50' long and 36' wide (6 beds, 6' wide). Randomized complete block with four replications was used during both years. Crimson and subterranean clover plots were strip-killed with glyphosate (Roundup) mid-April and then planted no-till in dead strips, two weeks later. For conventional production, rye plots were harrowed and deep-turned with a moldboard plow. Cotton (*Gossipium hirsutum* L.) was planted with modified no-till John Deere 71 planters. No fertilizers were applied to no-till plots with crimson clover and subterranean clover. All plots were irrigated as needed to average at least 1" per week.

No soil applied or foliar insecticides were used in no-till relay systems. In the 'Conventional System' Temik (7.0 lb/acre of 15G) was used for control of thrips and nematodes. Cotton in the conventional system also received six foliar applications of insecticides to control whiteflies, aphids, fall armyworms, and beet armyworms. For insect control in conventional plots, insecticides applied included one application of Monitor (1 pt./A), two applications of Lorsban (1 pt./A), two applications Lannate (2 pts./A) and one application of Ambush (12 oz./A).

For weed control, as mentioned above, only Glyphosate was applied two weeks before planting in no-till relay system plots. Areas between rows in no-till plots were mowed with a flail mower, 6-8 weeks after planting. Trifluarlin (treflan ½ lb/acre) was preplant incorporated for weed control in conventional plots. For full season weed control, conventional plots were cultivated and layby directed treatment of MSMA (2.5 pts./A) plus cotoron (1.5 qts./A) was applied six weeks after planting.

Grower's Field Plot

Research results with 'No-Till Relay Systems' were very encouraging, therefore, 15 lb/acre of crimson clover was planted in 7.2 acres in Coffee county during November, 1993. Crimson clover has re-seeded in this field from 1994 to 1998. From 1994-1997 (four years) the field was strip-tilled and planted with cotton during late April to mid-May. In 1998 cotton was planted with a no-till planter. Cotton cultivar DPL-90 was planted during the five years of this investigation.

Soil test results are presented in Table 2. To promote better seedling growth in furrow treatment, a 'Starter Solution' of 100 lb/acre of 10-34-0 was applied at planting during all five years and side-dressed with 200 lb ammonium nitrate per acre at bloom during 1994-98 (four years). In 1998, 300 lb of sulfate of potash-magnesia (sulpomag) was applied in addition to 200 lb of ammonium nitrate at bloom. This field was monitored by scouts regularly.

Weed control treatments were: glyphosate (Roundup), sprayed in 12 in. bands, two weeks prior to planting. Cotoron and Prowl were applied at planting and Bladex plus MSMA were applied 6 weeks after planting with hooded sprayer.

RESULTS AND DISCUSSION

Research Trials

Data from research studies conducted at the Coastal Plain Experiment Station has been summarized in Table 1. Crimson and subterranean clover were alive at the time cotton was planted. Crimson clover matured and died in late May and subterranean clover in mid-June. Subterranean clover was difficult to kill with herbicide glyphosate. Cotton plants in the no-till system were short with short internodes and produced bolls on the lowest branches. When compared with 'Conventional Systems' yield increase following crimson and subterranean clover under 'Relay Cropping System' was highly significant.

Very high numbers of beneficial insects were found in this field during two growing seasons in clover-cotton relay research plots. Pest insects were below threshold in these plots, therefore, no insecticides were applied to clover-cotton relay plots. Beneficial insect population was minimal and pest insect population was high in the conventional system. Insecticidal treatments were needed for white flies, aphids, fall armyworms, and beet armyworms.

Growers Field Plot

Encouraged by the success of these clover-cotton relay cropping systems at the research level a number of field plots were established in Fall, 1993. Data presented in tables 2, 3 and 4 are from one of these field plots that has been in continuous clover-cotton relay system since planting of clover in Fall, 1993.

Data presented shows that this 7.2 acre field produced higher cotton yields than state average during all five years. The state average includes irrigated cotton, also, while this was dryland cotton. Thus, this higher yield is even more significant. This 7.2 acre field showed no sign of water stress even during driest season. Overall crop growth was normal during all five years.

Pest Management

Thrips population in this field was low in spite of the fact Temik was not applied to this field. Pest insect population was low during five growing seasons and no insecticide applications were made. Few insects may be due to higher populations of beneficial insects observed in this field during all five cropping season. Scouting indicated

no need for insecticide application during all years. Most conventional cotton growers applied Temik and made an average of 3.5 insecticide applications each season to grow cotton during last five growing seasons.

Nutrient Removal

Nutrient removal was calculated by using data obtained from Zublena (1991) and presented in Table 4. Nitrogen removed by harvested seed cotton ranged from 48.73 to 61.74 lb/acre with an average removal of 55.94 lb/acre per year. Nitrogen application each year was about 70 lb/acre with most of it removed by the harvested crop. Conventional cotton growers apply 90 lb/acre to obtain similar yield. There was a reduction of 20 lb/acre of nitrogen in relay system compared with conventional production. In the research trials reported above, no fertilizer was applied to relay system cotton. In recent research there was no yield response to nitrogen with a clover relay system. Clover also added nitrogen to the fields. The amount of nitrogen added by a crop of clover varies greatly and depends upon the growth of the clover. Further research is needed to evaluate cotton response to nitrogen rates in a clover system.

Phosphorus removed by the cotton crop ranged from 19.34 to 25.50 lb/acre with an average removal of 22.39 lb/acre per year. The amount of phosphorus applied each year was 34 lb/acre with a total of 170 lb/acre during five years. Thus, 65.9% phosphorus applied was removed from the field by harvested crop. Conventional growers generally use the same amount of phosphorus as a starter solution.

Harvested cotton removed between 30.38 to 23.98 lb/acre of potassium with an average removal of 27.52 lb/acre per year. Total amount of potassium removed by harvested crop was 137.59 lb/acre during five years. While only 78 lb/acre was applied in 1998. It appears that clover crop is recycling and redistributing potassium from soil layer below sampling zone. Soil test results (Table 2) clearly demonstrate this redistribution.

During five years, harvested cotton crop removed a total of 17.77 lb/acre of calcium, 31.07 lb/acre magnesium, 22.20 lb/acre of sulfur, 0.80 lb/acre copper, 1.47 lb/acre of manganese, and 4.26 lb/acre of zinc. Of these nutrients 15 lb/acre of magnesium as sulfate of potash-magnesia (sulpomag) was applied in 1998. Sulfur was also applied as sulfate of potash-magnesia (sulpomag).

Nitrogen, potassium, magnesium, sulfur, and boron leach in sandy/sandy loam soils with low organic matter. Theoretically, if leaching is eliminated or substantially reduced it should be possible to maintain soil fertility at optimum levels by applying nutrients that have been removed by harvested crops. Clover-cotton relay cropping system with cover crops and conservation tillage has achieved this to some extent.

Soil analysis showed a substantial increase of phosphorus, potassium, calcium, magnesium, zinc, and manganese in top soil 4-5 months after planting clover. It appears that clover redistributed nutrients from below soil sampling zone to the sampling zone.

CONCLUSIONS

In 'Relay Cropping Systems' with legume cover crops and conservation tillage, cotton crops were grown with reduced fertilizer inputs and insecticide applications were not needed. Thus, these systems are economically feasible and environmentally friendly. More large scale adaptation is needed to understand weaknesses and strengths of these systems.

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Table 1. Comparison of Relay-cropped and Conventional Cotton, Tifton, Georgia.

Treatment	1992	1993	Total	Average
Crimson clover	5558 a**	5374 a	10932 a	5466 a
Subter. clover	5215 a	5109 a	10324 a	5162 a
Conventional	1659 b	1889 b	3548 b	1774 b

** Means within columns, followed by same letter not significantly different (Duncan's Multiple Range Test, p=0.01).

Table 2. UGA Soil Test Report Summary for 1993 to 1998 for Crimson Clover/Cotton Field (7.2 acre) of Wayne Fussell, Ambrose, Georgia (Coffee County).

Year/Month	P	K	Ca	Mg	Zn	Mn	pH
				lb/acre			
1993/Jan.	32 M	92 M	431	43	1	8	6.3
1994/Feb.	76 H	160 M	869	83	5	23	6.1
1995/Mar.	71 H	138 M	830	78	2	19	6.2
1996/Feb.	67 H	115 M	801	73	1	13	6.3
1997/Feb	59 M	95 M	665	66	1	17	6.1
1998/Apr.	47 M	65 L	495	58	1	20	5.6

Table 3. Yield of Cotton from 1994-1998 from 'Clover/Cotton Relay Cropping' Field (7.2 acre).

Year	Seed cotton	Bales	Lint	Seed	Seed Value	Lint/acre	State Avg.
			lb	lb	$	lb	lb/acre
1994	18345	14	7097	9785	440.33	985.69	843
1995	14480	10	4790	5880	274.35	665.28	644
1996	17520	14	6910	9260	416.70	959.72	747
1997	15820	10	4790	6477	339.52	665.28	646
1998	16920	12	6108	8369	439.37	848.33	500

Table. 4. Nutrient Removal (lb/acre) by Seed Cotton Harvested During 1994-1998.

Year	Yield	N	P_2O_5	K_2O	Ca	Mg	S	Cu	Mn	Zn
1994	18345	61.74	25.50	30.38	3.92	6.86	4.90	0.18	0.32	0.94
1995	14480	48,73	19.34	23.98	3.09	5.41	3.87	0.14	0.26	0.74
1996	17520	59.07	23.40	29.01	3.74	6.55	4.68	0.17	0.31	0.90
1997	15820	53.24	21.13	26.20	3.40	5.92	4.23	0.15	0.28	0.81
1998	16920	56.94	22.60	28.02	3.62	6.33	4.52	0.16	0.30	0.87
Removed	Total	279.72	111.97	137.59	17.77	31.07	22.20	0.80	1.47	4.26
	Avg.	55.94	22.39	27.52	3.55	6.21	4.44	0.16	0.29	0.85
Applied	Total	350.00	170.00	78.00		15.00	5.00			
	Avg.	70.00	34.00	15.60		3.00	1.00			