Planting and Termination Dates Affect Winter Cover Crop Biomass in a Conservation-Tillage Corn-Cotton Rotation: Implications for Weed Control and Yield

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Abstract

Use of the winter cover crops is an integral component of the conservation systems in corn (Zea mays L.) and cotton (*Gossypium hirsutum* L.). A field experiment was initiated in 2004 to evaluate weed suppression provided by winter cover crops in a conservation tillage corn and cotton rotation. Rotation for winter cover crops included clover (*Trifolium incarnatum* L.) preceding corn and rye (*Secale cereale* L.) preceding cotton. The winter cover crops were planted at five different planting dates based on thirty year average historical air temperature. Winter cover crop termination dates in the spring were 4, 3, 2 and 1 week prior to cash crop planting, also based on thirty year average historical soil temperature. Results showed a dramatic impact on biomass production with even a week's delay in winter cover crop planting and corresponding reduction in summer annual weed suppression. More than ten times difference in biomass produced by clover was observed at all the locations, when clover was planted on the earliest and terminated on last date compared to late planting and early termination. Rye produced almost eight times or more biomass in the same comparison. Weed biomass was 1551 kg ha^{-1} corresponding to rye biomass of only 274 kg ha^{-1} at Shorter in 2004. Weed populations in corn were low compared to cotton at all site years but weed control was not as predictable as in cotton. The data for the corn grain and cotton lint yield showed no significant relationship between cover crop biomass and the cash crop yield.

Introduction

Use of conservation tillage systems for cotton and corn production has become increasingly popular in the last two decades primarily to address concerns of decreasing air and water quality and soil productivity. Use of high residue cover crops is an integral component of conservation tillage systems. Cover crop residue provides soil with a cover which plays a vital role in reducing erosion, improving infiltration, soil moisture retention, carbon sequestration, increasing soil organic matter and nutrient recycling (Blevins et al. 1971; Bradley 1995; Kaspar et al. 2001).

Effective weed management throughout the growing season is a critical component in cotton production. Cotton can not compete effectively with weeds early in the season and presence of weeds late in the season can reduce the harvest efficiency and adversely impact lint quality. Approximately 90% of the cotton grown in United States in 2001 received herbicides (Anonymous 2002). Development of herbicide resistant weed species and shift in the weed populations are the results of such extensive chemical control. Practical alternatives to the intensive herbicides use in cotton offers potential economical as well as environmental benefits.

Winter cover crops also play an important role in weed suppression. Weed control by cover crops use is gaining more importance in today's conservation tillage systems since several weed species are acquiring resistance to herbicides. Previous research has shown that early season weed control by cover crops in conservation tillage systems is comparable to chemical control (Teasdale and Mohler, 1992; Johnson et. al. 1992). The degree of weed control provided by a cover crop depends on the management strategies. Living mulch cover crops suppress weeds by competition and by changing the light transmittance and soil temperature regimes (Teasdale and Dughtry, 1993). When killed, cover crop residues act as a physical barrier and create conditions difficult for weed seeds to emerge and establish. Previous research has shown that cover crops also suppress weeds through chemical allelopathic effects; however, field activity has not been widely documented due to difficulty of isolating the allelopathic effects from the physical mulch effects in field situations (Inderjit et al. 2001; Putnam et al. 1983).

Cereal rye (*Secale cereale* L.) and soft red winter wheat (*Triticum aestivum* L.) are the two most common winter cover crops recommended for cotton production in the southeastern United States. Both have been shown to possess allelopathic activity against weeds (Akemo et al., 2000; Perez and Ormeno-Nunez, 1991). Black oat (*Avena strigosa* Schreb.) has recently been introduced in the southeastern U.S. through a joint release between Auburn University and The Institute of Agronomy of Paraná, Brazil, and is currently marketed as "SoilSaver black oat" (Bauer and Reeves 1999). Recent research by Price et al. (2006) and Reeves et al. (2005) evaluated black oat as compared to rye and wheat in conservation-tillage cotton and soybean. Results showed that black oat biomass and weed suppressive potential is comparable to rye and greater than wheat, allowing for reduced herbicide input. Crimson clover, Austrian winter peas (*Pisum sativus* subsp. a*rvense*) and hairy vetch (*Vicia villosa* Roth) are the recommended cover crops for corn and they have also been shown to possess allelopathic activity (Stoll et al 2006).

Crop rotation is also an important for cotton production in the southeast since continuous cotton production causes many problems including increased soil borne pathogen populations. Lack of herbicide chemistry rotation also results in increased number of resistant weed species. Crop rotation can be an effective tool in reducing the buildup of problematic weeds thereby keeping their population under control. Using crop rotations with an effective herbicide program can help alleviate these problems. Rotations with corn are typical, due to the lower production costs, ease of production, and because corn is a non-host to many cotton pathogens.

Although weed control benefits associated with cover crops can be improved by increasing the amount of residue in the field, this can also result in some negative effects. High residue can interfere with cash crop establishment and can also deplete soil moisture (Teasdale, 1993). The dense residue can also lead to a decrease in soil temperature which can severely impact the cash crop yield. Therefore having an optimum amount of residue on the soil is maximizing the benefits of cover crops.

Historically, cover crop planting and termination have occurred at the discretion of growers' schedules and weather conditions. Research has shown that a winter cover's planting date and termination date has influence on both quality and quantity of residue production, and hence may affect subsequent weed suppression. A field study was conducted to determine optimum dates for planting and terminating cover crops so as to maximize biomass production and soil coverage, early season annual weed suppression, and cash crop yield.

Materials and Methods

Field experiments were conducted from autumn of 2003 at the Alabama Agricultural Experiment Station's E.V. Smith Research Center at Shorter, Al and Tennessee Valley Research and Extension Centers at Belle Mina, AL through corn harvest in 2006. An experiment was also conducted at the University of Florida's West Florida Education and Research Center at Jay, FL from autumn of 2004 to corn harvest in 2006. The soil types were Compass loamy sand (coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults) at E.V. Smith, Decatur silty loam (fine, kaolinitic, thermic, Rhodic Paleudult) at Tennessee Valley and Dothan sandy loam (Fine-loamy, siliceous, thermic Plinthic Kandiudults) at Jay Florida. The experimental design was a randomized complete block with three replicates having a split block restriction on randomization. Each plot had four rows of corn or cotton and both phases of the rotation were present each year.

The experiment involved two cover crops: rye preceding cotton and clover preceding corn rotated annually at each site. We examined five different planting dates and four different termination dates. Horizontal strips consisted of five cover planting dates and vertical strips consisted of four cover termination dates. Both covers were established with a no-till drill at 2 and 4 week prior to, 2 and 4 week after the 30 year average date of the first 0 C freeze. The rye seeding rate was 41 kg ha^{-1} and 56 kg of nitrogen (N) as ammonium nitrate was applied to rye in fall after establishment. The clover seeding rate was 11.4 kg ha^{-1}.

In the spring, covers were terminated at 4, 3, 2, and 1 week prior to cash crop planting with glyphosate at 1.12 kg ae ha^{-1} plus 2,4-D amine (0.20 kg ai ha^{-1}) utilizing a compressed CO_2 backpack sprayer delivering 140 L ha^{-1} at 147 kPa. Rye was flattened prior to glyphosate application with a mechanical roller-crimper to form a dense residue mat on the soil surface. Cover biomass from each plot was measured immediately before termination. The above-ground portion of rye and clover was clipped from one randomly-selected 0.25-m^2 section in each plot, dried at 60^0 C for 72 hours, and weighed.

The cotton varieties DP 444 BG/RR, ST 5242 BR and DP555BRR were planted at E.V. Smith, Tennessee Valley and Jay Florida, respectively. The corn variety Dekalb 69-72RR was planted at all the locations. Cash crops were planted with a four-row planter equipped with row cleaners and double-disk openers. Since both the E.V. Smith and West Florida sites had a well-developed hardpan, the experimental areas were in-row subsoiled prior to planting with a narrow-shanked parabolic subsoiler, equipped with pneumatic tires to close the subsoil channel. Weed biomass was determined in two 0.25-m^2 sections as described above when cotton reached the 4-leaf and corn reached 8-leaf growth stages. At this stage glyphosate was applied at 1.12 kg a.e. ha^{-1}. Plots were then kept weed-free until harvest utilizing Alabama Cooperative Extension System recommended herbicide applications. Though evaluations also included soil coverage by cover, cash crop stand establishment and height, and cash crop yield, in this paper we are only reporting the weed suppression provided by the two covers.

Results and Discussion

Different weather conditions encountered at the three locations resulted in large differences in biomass production. Maximum clover biomass production (5447 kg ha^{-1}) was observed at Shorter, AL in 2005 when crimson clover was seeded four weeks prior to the average first day of a 0 C freeze and terminated four weeks prior to planting the cash crop corn. The least biomass production

(0.72 kg ha^{-1}) was observed at Belle-Mina, AL in 2004 when the clover was seeded at the last establishment date (4-wk post 0 C freeze) and terminated four weeks prior to corn planting. Clover however suffered severe winter damage at Belle-Mina in 2004 and the biomass production was significantly low compared to other locations. At the southernmost location Jay, maximum clover biomass (1566.33 kg ha $^{-1}$) was produced when clover was planted four weeks prior to 0 C freeze and terminated three weeks prior to cash crop planting in year 2006.The lowest clover biomass observed at this location was 78 kg ha^{-1} in 2005 (Table 1).

Rye biomass was maximum (10953 kg ha $^{-1}$) in year 2004 at Belle-Mina when covers were planted on the first planting date and terminated only a week prior to the cash crop cotton planting. Biomass production was in general less at this location in other two years. At shorter the maximum biomass production was 8522.67 kg ha $^{-1}$ in year 2006 when rye planted two weeks before 0C freeze and terminated a week prior to cash crop planting. The lowest biomass produced at Shorter was 140 kg ha $^{-1}$ when covers were planted on the last planting date and terminated on the first planting date. At our southernmost location (Jay), rye biomass production was better in 2006 compared to 2005. Maximum observed rye biomass at this location was 7468 kg ha $^{-1}$ when rye was planted four weeks prior to 0 C freeze and terminated two weeks before the seeding of cotton (Table 3).

Weed control in corn was not as predictable as it was in cotton. Dry weights of weeds were however low in corn compared to cotton at all site years. This is likely due to the earlier sampling time in corn when fewer summer annual weeds have emerged. The cover crop biomass observed at these locations can explain some of the results observed for weed control. The lowest biomass observed was 0.67 Kg ha $^{-1}$ corresponding to clover biomass of 2453 kg ha $^{-1}$ at Shorter in 2006. Maximum weed biomass (407.33 kg ha $^{-1}$) in corn was observed at Belle-Mina in 2006 corresponding to clover biomass of 405.33 kg ha $^{-1}$ (Table 2).

In general, there was an increase in weed biomass in cotton with earlier termination and late planting of the rye cover crop. Maximum weed dry biomass observed was 1551.33 kg ha^{-1} corresponding to rye biomass of only 274.67 kg ha $^{-1}$ in 2004 at Shorter (Table 4). Less weed dry biomass was observed corresponding to a high rye cover crop residue. Our observations of decrease in weed biomass by corresponding increase in cover crop biomass agree with other research findings (Teasdale et al. 1991). Yenish et al. (1996) also reported better early season weed control by crimson clover than rye in no till systems.

None of the winter cover crop planting or winter cover crop termination dates had any effect on the establishment of the two cash crops through the heavy residue (data not shown). As the cash crop stands were not affected by the presence of the heavy winter cover crop residue on plots with earlier planting and later termination dates, there was no significant difference in the cotton lint and corn grain yields.

Conclusion

In general, winter cover crop biomass increased with the earlier planting and later termination and weed biomass decreased with increasing biomass. Observations indicate that high cover biomass should decrease early season weed interference and facilitate flexibility of POST application timing.

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Table 1: Effect of planting dates (PD) and termination dates (TD) on crimson clover biomass (kg ha $^{-1}$)

Planting Date	Termination Date	2004		2005			2006		
		Shorter	Belle Mina	Shorter	Belle Mina	Jay	Shorter	Belle Mina	Jay
PD 1	TD 4	821.33	4002.67	4910.67	1662.67	869.333	5002.67	3210.67	2756
PD 1	TD 3	1856.00	2841.33	4284.00	2204.00	461.333	4424.00	1965.33	2792
PD 1	TD 2	2877.33	2380.00	4358.67	2049.33	394.667	4942.67	1253.33	1566.77
PD 1	TD 1	1678.67	2221.33	5446.67	1796.00	677.333	3674.67	1186.67	1378.67
PD 2	TD 4	2944.00	2648.00	4710.67	2020.00	864.000	4701.33	1636.00	1510.68
PD 2	TD 3	1265.33	1432.00	3584.00	2928.00	336.000	4306.67	2085.33	1066.66
PD 2	TD 2	3032.00	1042.67	3722.67	2410.67	289.333	3954.67	2020.00	836
PD 2	TD 1	1297.33	616.00	3289.33	1985.33	381.333	2777.33	1272.00	502.66
PD 3	TD 4	980.00	830.67	1424.00	896.00	357.333	2496.00	1084.00	906.66
PD 3	TD 3	2037.33	822.67	1478.67	1133.33	149.333	1881.33	962.67	522.66
PD 3	TD 2	1409.33	462.67	612.00	917.33	152.000	2024.00	576.00	265.33
PD 3	TD 1	465.33	300.00	728.00	834.67	260.000	1429.33	405.33	164
PD 4	TD 4	2606.67	510.67	449.33	394.67	156.000	1153.33	588.00	358.66
PD 4	TD 3	1068.00	364.00	537.33	320.00	76.000	848.00	513.33	200
PD 4	TD 2	320.00	212.00	249.33	152.00	90.667	724.00	237.33	158.66
PD 4	TD 1	1288.00	128.00	198.67	184.00	89.333	496.00	185.33	102.67
PD 5	TD 4	1946.67	190.67	246.67	102.67	122.667	781.33	96.00	189.33
PD 5	TD 3	350.67	118.67	141.33	233.33	64.000	465.33	130.67	141.33
PD 5	TD 2	818.67	64.00	120.00	66.67	78.667	300.00	77.33	112
PD 5	TD 1	538.67	0.72	1149.33	82.67	93.333	152.00	34.67	84

Std Err = 441.44

Table 2: Effect of planting dates (PD) and termination dates (TD) on weed biomass (kg ha $^{-1}$) in corn

Planting Date	Termination Date	2004		2005			2006		
		Shorter	Belle Mina	Shorter	Belle Mina	Jay	Shorter	Belle Mina	Jay
PD 1	TD 4	30.00	64.67	24.67	32.67	27.33	4.67	10.00	10.67
PD 1	TD 3	16.00	59.33	85.33	17.33	21.33	0.67	18.00	35.33
PD 1	TD 2	6.67	108.00	33.33	17.33	22.00	2.00	77.33	16.67
PD 1	TD 1	50.67	93.33	104.67	42.00	33.33	57.33	340.00	250.00
PD 2	TD 4	19.33	69.33	90.67	10.00	104.67	4.67	37.33	85.33
PD 2	TD 3	22.67	74.00	124.00	34.67	28.00	2.67	18.67	8.67
PD 2	TD 2	12.67	142.67	78.67	153.33	66.67	12.67	216.00	52.67
PD 2	TD 1	56.00	126.67	188.00	44.67	87.33	51.33	203.33	84.00
PD 3	TD 4	31.33	134.00	89.33	184.67	34.67	15.33	123.33	34.00
PD 3	TD 3	191.33	182.67	198.00	24.00	22.00	10.00	75.33	17.33
PD 3	TD 2	79.33	170.00	140.00	299.33	28.67	46.00	152.00	43.33
PD 3	TD 1	29.33	131.33	117.33	161.33	83.33	126.00	407.33	44.67
PD 4	TD 4	45.33	108.67	66.67	427.49	23.33	21.33	75.33	33.33
PD 4	TD 3	48.67	185.33	89.33	73.85	12.00	19.33	150.00	411.33
PD 4	TD 2	126.00	172.00	86.00	177.33	102.00	35.33	196.67	35.33
PD 4	TD 1	78.67	145.33	117.33	4.67	74.00	323.33	262.67	89.33
PD 5	TD 4	72.00	282.67	144.67	129.33	33.33	143.33	118.00	255.33
PD 5	TD 3	100.00	188.67	84.00	62.00	29.54	50.00	102.67	31.33
PD 5	TD 2	115.33	118.00	46.67	156.67	51.33	60.00	154.00	61.33
PD 5	TD 1	147.33	159.33	182.67	192.67	107.33	177.33	339.33	306.00

Std Err = 62.89

Table 3: Effect of planting dates (PD) and termination dates (TD) on rye biomass (kg ha $^{-1}$)

Planting Date	Termination Date	2004 Shorter	2004 Belle Mina	2005 Shorter	2005 Belle Mina	2005 Jay	2006 Shorter	2006 Belle Mina	2006 Jay
PD 1	TD 4	4506.67	10953.33	5234.67	6734.67	3713.33	6252.00	7942.67	5333.33
PD 1	TD 3	7534.67	10277.33	4960.00	6680.00	4273.33	6549.33	5520.00	7468.00
PD 1	TD 2	6800.00	8545.33	5690.67	3772.00	3876.00	6904.00	7465.33	4174.67
PD 1	TD 1	3421.33	5737.33	5438.67	3061.33	2557.33	5002.67	4656.00	3049.33
PD 2	TD 4	5488.00	8997.33	4678.67	8741.33	2566.67	8522.67	5166.67	6500.00
PD 2	TD 3	6157.33	9369.33	6374.67	5709.33	4556.00	6532.00	4356.00	6370.67
PD 2	TD 2	5733.33	7086.67	5024.00	4418.67	2964.00	5670.67	4169.33	5358.67
PD 2	TD 1	2833.33	5953.33	3496.00	2060.00	1842.67	4349.33	2620.00	3134.67
PD 3	TD 4	4888.00	8933.33	2477.33	3496.00	3478.67	8053.33	3554.67	5806.67
PD 3	TD 3	4850.67	6706.67	3344.00	3349.33	3078.67	5224.00	2644.00	5249.33
PD 3	TD 2	5765.33	5744.00	2584.00	2692.00	2122.67	4681.33	1896.00	4497.33
PD 3	TD 1	1873.33	4950.67	2033.33	1913.33	1554.67	3529.33	1822.67	3226.67
PD 4	TD 4	3024.00	6934.67	745.33	3254.16	1674.67	2554.67	4336.00	3926.67
PD 4	TD 3	3616.00	3710.67	533.33	2200.00	1957.33	2880.00	4074.67	4301.33
PD 4	TD 2	3693.33	3517.33	488.00	1749.33	1576.00	3012.00	2248.00	3222.67
PD 4	TD 1	784.00	3836.00	304.00	1117.33	1540.00	1766.67	1682.67	1945.33
PD 5	TD 4	2030.67	4654.67	292.00	1402.67	1630.67	1792.00	2624.00	2633.33
PD 5	TD 3	1497.33	2042.67	234.67	898.67	1774.67	1305.33	2601.33	3460.00
PD 5	TD 2	1302.67	2408.00	184.00	833.33	1222.67	1652.00	1838.67	2822.67
PD 5	TD 1	274.67	1490.67	140.00	517.33	1552.00	730.67	1198.67	1908.00

Std Err = 743.99

Table 4: Effect of planting dates (PD) and termination dates (TD) on weed biomass (kg ha $^{-1}$) in cotton

Planting Date	Termination Date	2004 Shorter	2004 Belle Mina	2005 Shorter	2005 Belle Mina	2005 Jay	2006 Shorter	2006 Belle Mina	2006 Jay
PD 1	TD 4	103.33	38.67	87.33	20.00	33.33	56.00	58.67	18.00
PD 1	TD 3	37.33	33.33	179.33	82.00	58.00	65.33	115.33	32.00
PD 1	TD 2	158.67	14.67	410.67	153.33	8.00	34.00	412.67	71.33
PD 1	TD 1	966.00	38.67	477.33	278.00	93.33	91.33	268.00	91.33
PD 2	TD 4	68.67	13.33	168.67	32.67	49.33	2.67	197.33	10.00
PD 2	TD 3	258.67	20.67	394.00	95.33	40.00	26.00	207.33	42.00
PD 2	TD 2	212.00	60.00	314.67	339.33	37.33	65.33	536.67	53.33
PD 2	TD 1	734.00	121.33	646.67	262.00	73.33	119.33	878.67	86.67
PD 3	TD 4	26.00	591.33	134.67	135.33	62.67	8.00	342.00	22.67
PD 3	TD 3	311.33	186.67	533.33	202.00	54.00	31.33	862.67	62.00
PD 3	TD 2	522.00	247.33	462.00	371.33	78.67	74.00	1457.33	120.00
PD 3	TD 1	1019.33	599.33	629.33	390.67	124.67	117.33	1118.67	148.00
PD 4	TD 4	197.33	341.33	160.67	202.67	51.33	10.67	256.00	28.00
PD 4	TD 3	340.67	238.67	362.00	112.67	50.67	80.00	492.00	46.67
PD 4	TD 2	321.33	224.00	441.33	483.33	44.00	113.33	546.00	89.33
PD 4	TD 1	1036.00	197.33	902.67	391.33	67.33	121.33	178.67	177.33
PD 5	TD 4	123.33	452.67	151.33	612.67	125.33	10.00	505.33	20.67
PD 5	TD 3	759.33	284.67	476.00	258.67	50.67	167.33	444.67	73.33
PD 5	TD 2	1445.33	276.67	522.67	638.67	74.00	34.00	824.67	79.33
PD 5	TD 1	1551.33	366.67	361.33	404.00	96.00	142.00	882.00	88.00

Std Err = 160.89