Effects of soybean residue management and tillage on corn yields

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Soybean is recognized for its apparent N contributions and yield-enhancing effects in crop sequences. Since soybean is often grown in rotation with corn, most states suggest a reduction in N fertilizer rates for corn following soybean relative to corn following corn. Nitrogen balance studies suggest that soybean harvested for grain removes more N than the crop accumulates through symbiotic N fixation. This suggests that the apparent soybean N effect may be caused by factors other than a direct contribution of fixed N to a subsequent crop.

Numerous studies have attempted to quantify the soybean N contribution and to elucidate the mechanisms involved in this phenomenon. Recently, a group of Midwestern states adopted an alternative approach to N rate suggestions for corn following soybean by basing these rates on results of corn N response experiments obtained where soybean was the previous crop. This alternative approach essentially treats the soybean–corn crop sequence as a separate cropping system that includes the soybean N effect, but it requires a substantial N response database to derive the N rate suggestions.

Substantial year-to-year and site-to-site variability in the apparent soybean N contribution have been reported. The range of management practices used in corn–soybean rotations such as tillage and residue management could account for some of this variability by altering N cycling and N availability. As a result, questions remain about factors affecting the soybean N contribution.

There is interest in removing soybean residue after grain harvest and using it as a biofuel or feed or bedding for livestock and in harvesting immature soybean as forage. The removal of soybean plant material either as a forage or as residue can affect potential changes in soybean N contributions by negatively influencing soil organic matter levels, structure, storage, movement of water and air, and N availability. Since soybean is a major crop in the Midwest and economic and environmental incentives to avoid excess N fertilizer applications are likely to continue or expand, the need for field-specific techniques to estimate soybean N contributions becomes more important. However, little information exists on the effects of soybean residue management on soybean N contributions.

In the July–August 2010 issue of *Agronomy Journal*, researchers report on a study in which they sought to determine: (i) soybean forage harvest and soybean residue management effects on grain yields and N availability to a subsequent corn crop and (ii) corn response to applied N where soybean was the previous crop on a range of soils widely used for corn and soybean production.

Field experiments to evaluate the effects of soybean harvest management system (HMS) on soybean N contributions where corn follows soybean were established at four locations in 1993 through 1996. The effects of returning or removing soybean residue, soybean forage harvest at the R6 growth stage, and applied N on corn grain yields were determined for three years at four locations on

Table 1. Effects of soybean harvest management system (HMS) and N fertilizer rate on corn grain yield, and economic optimum N rates at four locations, 1994 to 1996.

Year	Location	HMS†	N fertilizer rate, lb/ac 0	40	80	121	161	Economic optimum N rate
			Yield, bu/ac‡					lb/ac
1994	Arlington	1, 2, and 3	184	201	198	201	205	40
	Lancaster	1, 2, and 3	125	163	194	209	222	161
	Platteville	1, 2, and 3	199	195	196	198	201	0
	Belmont	1, 2, and 3	180	196	218	211	207	80
1995	Arlington	1, 2, and 3	169	172	176	173	170	80
	Lancaster	1	143	162	157	170	169	121
	Lancaster	2 and 3	151	159	150	141	140	0
	Platteville	1, 2, and 3	140	154	151	154	152	40
	Belmont	1, 2, and 3	162	170	169	174	168	40
1996	Arlington	1	141	158	166	164	170	90
	Arlington	2 and 3	158	169	170	173	172	54
	Lancaster	1, 2, and 3	166	183	188	190	191	55
	Platteville	1	143	180	200	218	201	113
	Platteville	2 and 3	181	213	200	211	211	35
	Belmont	1, 2, and 3	173	192	210	212	207	76

† 1 = soybean residue returned; 2 = soybean residue removed; and 3 = soybean forage harvested.

‡ Averaged across all harvest management systems (HMS), except where noted.

medium-textured soils typical of those used for soybean production in Wisconsin. Research locations were the University of Wisconsin–Platteville research farm near Platteville on a Tama silt loam (fine-silty, mixed, superactive, mesic Typic Argiudolls); the University of Wisconsin Agricultural Research Station at Lancaster on a Rosetta silt loam soil (fine-silty, mixed, superactive, mesic Typic Hapludalfs); a private farm near Belmont, WI on a Tama silt loam; and the University of Wisconsin Agricultural Research Station at Arlington, WI on a Plano silt loam soil (fine-silty, mixed, superactive, mesic Typic Argiudolls).

Initial soil tests for pH, organic matter, available P, and exchangeable K were performed at all locations before planting soybean. Soil test results showed that available P and exchangeable K at all locations were in the high or excessively high categories for corn, according to Wisconsin's soil test recommendations.

Nitrogen rate and soybean harvest management effects on corn yields

Corn grain yield was significantly increased by applied N each year at all locations, except for Platteville in 1994 and Lancaster in 1995 (Table 1). The Platteville site received manure additions in 1992, which resulted in high N mineralization and subsequent high soil NO_3–N values that prevented corn yield response to added N in 1994. Corn yields at Lancaster in 1995 did not show a response to added N; however, there was a significant N × HMS interaction. At this site, the soybean forage harvest and residue-removed HMS treatments did not respond to N rate, but yields in the residue-returned treatment increased in response to applied N (Table 1). Soybean harvest management significantly affected corn grain yields at Arlington and Platteville in 1996. In both cases, the residue-returned treatment had lower corn yields and required more applied N to optimize yields than the residue-removed or soybean forage treatments (Table 1). Corn yields also tended to be lower with soybean residue returned at other locations and years; however, this lower yield was not significant at the $p \leq 0.05$ level (data not shown). In addition, tillage did not significantly affect yields at Arlington in 1995 or 1996, and chisel plow or no-till had no significant interactions with N rate or HMS.

Economic optimum N rates (EONR) for corn after soybean ranged from 0 to 161 lb/ac in 1994, 0 to 121 lb/ac in 1995, and 35 to 113 lb/ac in 1996 (Table 1). These results confirm earlier research showing that there is substantial variation across sites and years in the apparent soybean N contribution to a following corn crop. Where soybean HMS significantly affected subsequent corn grain yields, the soybean residue-returned treatment had a higher EONR than where residue was removed or soybean forage was harvested.

According to Wisconsin N recommendations for continuous corn, about 160 lb N/ac would be recommended at all of the research locations; therefore, the observed variation in EONR across sites and years (Table 1) indicates that applying typical soybean N credits of 27 to 40 lb/ac usually does not accurately reflect the observed N needs for corn following soybean.

Soybean grain and dry matter yields

Since the management of soybean residue may help to identify the mechanisms involved in apparent soybean N contributions and soybean effects on subsequent corn grain yields, it is important to consider soybean grain yields and N content of the residues removed or returned in soybean HMS. Soybean grain yields ranged from 38 to 66 bu/ac across sites and years. These yields were not well related ($r^2 = 0.09$) to the EONR for subsequent corn crops. This suggests that corn N rate adjustments to account for the effects of a previous soybean crop on soils similar to those used in this study should not be based on soybean yield.

The soybean forage and soybean residue N concentration and total N content for all locations are shown in Table 2. The amount of N in soybean residue is relatively small, and the decomposition rate is rapid compared with corn residue. In the current study, returning soybean residue to the soil affected subsequent corn yields or corn N response (N × HMS interaction) in 3 of 12 site-years. Where these effects were significant, return of the residue resulted in a higher EONR for corn (Table 1), indicating that N release from soybean residue is not a major source of the apparent soybean N contribution.

Table 2. Average N concentration and N content in soybean forage and soybean residue at four locations, 1993 to 1995.

Year	Soybean material	Nitrogen concentration	Dry matter	Nitrogen content
		%	tons/ac	lb/ac
1993	forage	3.0	267	165
	residue	0.8	142	24
1994	forage	2.8	528	293
	residue	0.8	334	54
1995	forage	2.6	460	236
	residue	0.8	313	53

Soybean residue management effects on soil nitrate-nitrogen

Soil samples collected from the top 12 inches of soil when the corn was 6 to 12 inches tall (pre-sidedress) often showed that the forage removed or the grain harvested with the residue-removed treatments had somewhat greater soil NO_3–N content than the grain harvested with the residue-returned treatment (Tables 3 and 4). Although some of the differences in soil NO_3–N content between soybean residue management treatments were significant, these differences were usually small and did not affect corn grain yields or optimum N rates (Table 1). The increase in soil NO_3–N content in the forage-harvested and residue-removed treatments, relative to the residue-returned treatment, is probably a result of warmer soil temperatures where forage or residue was removed. In the current study, average surface soil temperatures during June 1995 and 1996 were warmer in the soybean residue-removed and forage-harvested treatments. After June, this difference in soil temperature diminished due to corn canopy closure. Warmer soil temperatures should stimulate soil N mineralization where soybean forage or residue is removed, but immobilization of soil NO_3–N in the residue-returned treatment could also contribute to lower soil NO_3–N in this treatment.

Soil NO_3–N contents (0 to 12 inches) measured in the N rate control treatment at 7- to 14-day intervals during the 1994 and 1995 corn growing seasons at Arlington illustrate the influence of HMS treatments on temporal changes in the amounts of NO_3–N in the soil. Changes in soil NO_3–N during the growing season were similar in all HMS treatments. Net mineralization of N from early spring (April) through early summer (June) resulted in soil NO_3–N accumulation followed by a period of N removal by corn during its period of rapid N utilization (July). For the remainder of the growing season, soil NO_3–N values were relatively constant. The small difference in soil NO_3–N between HMS throughout the growing season did not significantly affect corn yields in 1994 or 1995. These results support the conclusion that N release from soybean residue is not a major contributor to soybean effects on subsequent corn yield or N response. Tillage effects on soil NO_3–N content show that the chisel plow treatment had greater NO_3–N than no-till, especially early in the growing season (May through June). This difference is probably due to increased N mineralization from warmer soil temperatures in the chisel plow plots. This

Table 3. Effect of soybean harvest management system (HMS) on soil N test values in no-till corn at four locations in 1994 and three locations in 1995 and 1996.

		Soil N test depth, inches‡								
		1994			1995			1996		
		PPNT	PPNT	PSNT	PPNT	PPNT	PSNT	PPNT	PPNT	PSNT
Location	HMS†	(0–35)	(0–12)	(0–12)	(0–35)	(0–12)	(0–12)	(0–35)	(0–12)	(0–12)
		NO_3–N, lb/ac	ppm NO_3–N, ppm		NO_3–N, lb/ac	NO_3–N, ppm		NO_3–N, lb/ac	NO_3–N, ppm	
Arlington	1	44 b§	8	23						
	2	65 a	11	23						
	3	59 ab	10	19						
p > *f*		0.08	0.12	0.25						
Lancaster	1	38	4	13 b	79	6	11 b	78 b	11 b	10 b
	2	38	5	16 ab	85	9	23 a	101 a	16 a	14 a
	3	39	5	17 a	92	9	23 a	90 a	14 a	15 a
p > *f*		0.95	0.56	0.10	0.52	0.11	0.05	<0.01	<0.01	0.02
Platteville	1	104 b	16 b	37	87	5 b	9 b	71 b	8 b	7
	2	129 b	20 b	37	77	6 ab	11 ab	75 b	9 ab	7
	3	201 a	30 a	40	88	8 a	13 a	89 a	11 a	11
p > *f*		0.01	0.01	0.88	0.60	0.10	0.08	0.01	0.10	0.20
Belmont	1	83	11 ab	20	97	9	13 b	59 c	5 b	6
	2	81	10 b	20	109	9	25 a	86 a	10 a	11
	3	96	13 a	25	113	10	23 a	74 b	5 b	9
p > *f*		0.34	0.10	0.33	0.73	0.94	0.01	<0.01	<0.01	0.15

† 1, grain harvest with residue returned; 2, grain harvest with residue removed; 3, harvested as forage at R6.

‡ PP, preplant; PS, presidedress; NT, nitrate test.

§ Mean values for each location followed by the same letter are not significantly different at the 0.10 probability level.

trend continues through mid-June when corn growth rapidly depletes the N supply, and by mid-July, there are no significant differences in soil NO_3–N between the chisel plow and no-till systems.

Comparison of surface (0 to 12 inches) soil NO_3–N contents at preplant (PPNT) and presidedress (PSNT) sampling times (Tables 3 and 4) shows that soil NO_3–N increased as expected at all locations in 1994 and 1995 but not in 1996. These results are likely due to excessive rainfall at all sites during June 1996, which probably caused leaching of NO_3–N below the 12-inch sampling depth and/or promoted NO_3–N loss through denitrification. Although growing season precipitation at the Lancaster and Platteville/Belmont locations was less than the 30-year average (Table 2), June 1996 precipitation was substantially greater than the 30-year average for June at all three locations (data not shown). Most of this precipitation occurred before the PSNT samples were collected in 1996.

Table 4. Effect of soybean harvest management system (HMS) and tillage on soil N test values at Arlington, 1995 and 1996.

		Soil N test depth, inches‡					
		1995			1996		
		PPNT	PPNT	PSNT	PPNT	PPNT	PSNT
Tillage	HMS†	(0–35)	(0–12)	(0–12)	(0–35)	(0–12)	(0–12)
		NO_3–N, lb/ac	NO_3–N, ppm		NO_3–N, lb/ac	NO_3–N, ppm	
No-till	1	95	8	18	75	9	7
	2	93	8	25	76	11	12
	3	107	8	20	115	15	11
Chisel plow	1	92	8	25	69	9	9
	2	82	7	29	97	12	8
	3	90	7	22	96	14	9
No-till		98	8	21 b§	88	12	10
Chisel plow		88	7	25 a	88	12	9
	1	93	8	22 b	72 c	9 b	8
	2	88	8	27 a	87 b	12 b	10
	3	98	8	21 b	105 a	19 a	10
		Statistical information					
Tillage	$p > f$	0.35	0.63	0.05	0.71	0.97	0.12
HMS	$p > f$	0.25	0.95	0.03	0.04	0.01	0.36
Tillage × HMS	$p > f$	0.55	0.59	0.46	0.23	0.61	0.09

† 1 = grain harvest with residue returned; 2 = grain harvest with residue removed; and 3 = harvested as forage at R6.

‡ PP, preplant; PS, presidedress; NT, nitrate test.

§ Mean values within each column followed by the same letter are not significantly different at the 0.10 probability level.

Conclusions

Economic optimum N rates for corn following soybean varied substantially across sites and years but were not greatly affected by soybean HMS or tillage at most sites. Optimum N rates for corn were not related to previous soybean crop yield, indicating that adjustments in corn N rates following soybean should not be based on soybean yield. Results also indicate that soybean forage harvest and residue management have little effect on subsequent corn grain yields. Where there were significant effects, the soybean residue-returned treatment required more fertilizer N to maximize yields. This significant effect may be the result of either greater soil NO_3–N in the soybean residue-removed or soybean forage harvest treatments due to increased N mineralization from warmer soil temperature or N immobilization from the soybean residue returned. These findings also suggest that N in soybean residues is not a major source of the apparent soybean N contribution. The surface soil (0- to 12-inch) NO_3–N values over time show that all soybean HMS follow a similar pattern in net N mineralization and N removal by corn and that early in the growing season, chisel plow may have significantly greater soil NO_3–N content than no-till in some years.

Adapted from the Agronomy Journal *article, "Soybean Residue Management and Tillage Effects on Corn Yields and Response to Applied Nitrogen," by K.A. Schoessow, K.C. Kilian, and L.G. Bundy. Agron. J. 102:1186–1193.*