CEREAL GRAIN COVER CROP PERFORMANCE IN VIRGINIA

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ABSTRACT

A Virginia study evaluating cover crop species at three plating dates with or without winter nitrogen application determined that rye and rye + hairy vetch yielded significantly more biomass than other species. Rye nitrogen uptake was also greater than other cereals. Early planted rye reduced total soil profile NO_3^- (0-36 in) by 13 lb ac^{-1}. Across species, early planting resulted in 19 lb ac^{-1} less soil profile NO_3^- in May than late planting. Averaged over cereal cover crops, N applied at GS 25 resulted in 1.0 ton ac^{-1} more biomass and 23 lb ac^{-1} more N uptake.

INTRODUCTION

Improved water quality in the Chesapeake Bay has been a long-term concern in Virginia and other Mid-Atlantic states. Today, the importance of water quality, and the role of agriculture in maintaining water quality, is apparent throughout the United States. The Chesapeake 2000 agreement, a strategic plan to maintain abundant, diverse populations of living resources, fed by healthy streams and rivers, sustain strong local and regional economies, and maintain quality of life in the region was adopted in June 2000 (Chesapeake Bay Program, 2000). Chesapeake 2000 calls for the development of locally supported watershed management plans in two-thirds of the Bay watershed. These goals make it imperative that growers utilize land and nutrient resources efficiently. Winter annual cover crops are an important tool for water quality protection because they can scavenge and utilize soil nutrients, especially nitrogen (N), which could otherwise be lost from the soil/plant system through leaching and runoff during winter months.

Beneficial effects of cover crops and crop rotation have been recognized for many years. As early as 3000 years ago, growers were using green manure cover crops to improve soil fertility. However, the steady increase of inorganic fertilizer use over the past 60 years and the development of more modernized farming techniques have resulted in less diversified cropping systems. Increasing environmental concerns associated with fertilizer lost from the agricultural system, soil erosion, and high production costs coupled with low commodity prices have led many growers to reexamine cover cropping as a method of increasing soil productivity.

Soil organic matter (SOM) content directly influences many biological, chemical, and physical properties that affect productivity. The greatest contributor to SOM is crop residue. Soil organic matter can hold up to 20 times its weight in water (Stevenson, 1982). This can significantly increase the amount of plant-available water, particularly in sandy soils. Even in high-rainfall regions, moisture is often a limiting factor in crop production, therefore, greater plant-available water, due to higher SOM content, can increase yield by improving the overall water use efficiency (crop yield per unit of water; WUE) of the crop.

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The crumbly, friable, well-aerated soil structure associated with good tilth is desirable due to improved drainage, reduced crusting and ponding, and ease of seedbed preparation for following crops. Crop rotation improves soil structure by reducing the impact of compaction by increasing aggregate stability. As early as 1967, researchers noted that aggregate stability increased from 67 to 76% when alfalfa was added to a corn-barley-sugarbeet rotation (Schumaker et al., 1967). More recently, similar results have been published documenting that aggregate stability is consistently higher under legume (alfalfa or red clover)-corn rotations compared with continuous corn (Raimbault and Vyn, 1991). Increased aggregate stability also reduces erosion by making the soil less vulnerable to the destructive forces of wind and rain.

Research cited by Peel (1998) found greater than 50% reduction in soil erosion when corn, barley, and hay were rotated compared with soil erosion from land in continuous corn. The decrease in soil loss when crop rotation and cover crops are employed is due to several factors. These factors include the dense canopy of the forage, reduced cultivation when the soil was in forage, the more extensive root system of the forage, and the increased amount of residue returned to the soil as a result of crop rotation. Reduced soil loss not only benefits crop production, but also decreases the potential for surface runoff of sediment containing nutrients and pesticide residues.

Therefore the objectives of this research were to: 1) Determine the winter cover crop species and planting date that provides the most vigorous winter soil cover, the greatest biomass return to the soil system, and the highest level of N uptake; 2) Determine the change in soil nitrate (NO_3^-) from the beginning to the end of cover crop season; 3) Evaluate cover crop effects on subsequent crop weed control; and 4) Educate producers and agricultural professionals on how to successfully implement cover crops to maximum environmental and economic advantage.

MATERIALS AND METHODS

1. Determine the winter cover crop species and planting date that provides the most vigorous winter soil cover, the greatest biomass return to the soil system, and the highest level of N uptake.

One experimental site was established annually on the Davis farm in the Coastal Plain of Virginia in a split plot design with two replications. Main plots were crop species or mix (Rye, Oats, Barley, and Triticale in 2005; and Rye, Oats, Barley, Crimson Clover, Vetch, and Rye+Vetch in 2006 and 2007) and planting date (approx. Oct. 1, Oct. 20, and Nov 10), sub plots were spring N rate (0, 25, 50 or 0 and 30 lb N ac^{-1} in 2005 and 2006-2007, respectively). Seeding was performed with a Great Plains no-till grain drill in plots that were 20 by 300 feet. Urea ammonium nitrate liquid (30% N) was the winter N source. Aboveground biomass was hand clipped from a 1.6 ft^{-2} area in each treatment at in mid-winter, prior to N application, and crop samples were dried in a forced air oven at 60°C for 48 hr dry matter yield determined dry matter yield. All aboveground biomass was again hand clipped from a 1.6 ft^{-2} area in each treatment just prior to killing the cover crop. Crop samples were again dried in a forced air oven at 60°C for 48 hr and then ground to pass a 2 mm screen using a Wiley (Thomas Scientific, Swedesboro, NJ) sample mill and total N determined by dry combustion (Leco Corp., St. Joseph, MI). Nitrogen uptake was determined as the product of dry matter yield and tissue N concentration.

2. Determine the change in soil nitrate (NO_3) over the cover crop season.

A composite sample to a depth of three feed in increments of 0-6, 6-12, 12-24, and 24-36 in was taken from the study site prior to cover crop planting each fall. At the time of cover crop termination, each plot was soil sampled by taking and compositing three cores to a depth of 3 feet in increments of 0-6, 6-12, 12-24, and 24-36 in. Samples were dried in a forced air oven at 60°C for 48 hr and then ground to pass a 2 mm screen using hand processing. Soil samples were extracted using 2M KCl (Bremner, 1965) and analyzed for NH_4-N and NO_3-N using automated flow injection analysis (Lachat Inst., Milwaukee, WI).

3. Evaluate cover crop effects on subsequent crop weed control.

Weed pressure was subjectively evaluated during early season growth of the following pumpkin crop. Photographs were taken for use as a teaching tool, especially as related to pumpkin shell quality.

RESULTS

Analysis of variance revealed a significant effect of crop species and planting date on biomass yield and nitrogen uptake in all three years (Table 1). There was a significant interaction of these factors for both yield and N uptake in 2007 caused by the vetch treatment where yield and N uptake increased with later planting. Application of spring N resulted in a significant increase in biomass yield across species in all instances and increased N uptake in 2005 and 2007 (Table 1). There was a significant interaction of crop and N rate for both yield and N uptake in 2007. This was due to the inclusion of legume and legume mix cover crops. Cereal cover crops alone did not exhibit this interaction.

Biomass

Over years, cereal cover crops planted early produced approximately 1.1 ton ac^{-1} more biomass than late plantings. Rye grew the most biomass, producing an average of 6.2, 5.5 and 3.4 ton ac^{-1} at the early, mid, and late plantings, respectively.

In 2005, rye produced more than twice the total biomass of any other species (Figure 1). Even late planted rye produced more than early planted triticale and barley. Oats produced the least biomass with average total production of 1.6 ton ac^{-1}. Rye and the rye+vetch mix produced the greatest biomass in 2006 (Figure 1) with both treatments producing over 5.4 ton ac^{-1} with early or mid planting. Early planted barley produced nearly 3.6 ton ac^{-1}, which was similar to 2005, however total biomass dropped dramatically with the mid and late planting date. Vetch alone, planted early, produced over 4.5 ton ac^{-1} indicating an exceptional ability to fix nitrogen for the following crop. In 2007, rye and rye+vetch again produced the greatest biomass with an average of 5.0 and 5.2 ton ac^{-1}, respectively. Barley and crimson clover biomass decreased approximately 40 % from the early to the late planting date (Figure 1). Early planted oats were severely damaged by deer grazing soon after emergence and this treatment was dropped. Early planted rye+vetch produced a total of 5.9 ton ac^{-1} while the average of all early planted cereals was 3.6 ton ac^{-1} and that of early planted legumes was 2.8 ton ac^{-1} (Figure 1).

Nitrogen Uptake

Over years, the highest levels of N uptake were observed in the vetch and rye+vetch treatments (247 and 197 lb ac^{-1}averaged over planting date). The average N uptake of early planted cereal crops was 84 lb ac^{-1} while that of early rye was 132 lb ac^{-1}. This same trend was evident for the late planting with the average over crops of 59 lb ac^{-1} and rye at 83 lb ac^{-1}.

Similar to the trend observed in 2005 biomass production, N uptake was highest for rye. None of the other cereal cover crop treatments took up over 89 lb N ac^{-1} but even late planted rye took up 99 lb ac^{-1} (Figure 1). In 2006, vetch and the combination of rye+vetch captured the most N with 220 and 136 lb N ac^{-1} taken up across planting dates, respectively (Figure 1). Average N uptake for early planted cereal cover crops was 92 lb ac^{-1} while that for rye planted early was 115 lb ac^{-1}. Early planted vetch resulted in over 297 lb ac^{-1} of N uptake by early May. In 2007, all planting dates of vetch alone or rye+vetch produced over 223 lb ac^{-1} N uptake (Figure 1). Average N uptake for early planted cereals was 109 lb N ac^{-1} while crimson clover uptake was 158 lb ac^{-1}.

Response to Spring N

While there was an overall interaction of N rate and crop species in 2007, this was due to the expected lack of N response in the legume treatments. Response of the cereal grain cover crops to spring N is presented in Table 2. In 2005, rates of 0, 25 and 50 lb ac^{-1} were applied at Zadoks GS 25, resulted in 1.3 ton ac^{-1} more production for the first increment and 0.2 ton ac^{-1} for the second increment. Total N uptake was increased by 29 lb ac^{-1} with the application of 25 lb N ac^{-1} as UAN fertilizer. This application likely increased the competitive ability of the crop and allowed it to scavenge even more N from the soil. The application of 50 lb N ac^{-1} increased N uptake by only 10 additional lb, so in future years, the winter N application was limited to 30 lb ac^{-1}. Over the 2006 and 2007 crop years, adding 30 lb N ac^{-1} resulted in an average increase of .65 ton ac^{-1} more biomass and 23 lb ac^{-1} more N uptake. This response indicates that low rates of N can be applied at GS25 to improve biomass production with little overall impact to soil NO_3 because of the high efficiency of uptake at this time.

Soil Nitrate Levels

Preplant soil nitrate levels decreased from 33 lb ac^{-1} in the top 12 in to 20 lb ac^{-1} by the third year of the study (Table 3). This was not the cumulative effect of these treatments over time; this study was moved to different fields in different years to match the crop rotation. However, it does represent the adoption of winter cereal cover crops on the entire farm and the effect cover crops can have in a fairly short time frame. Similarly, the sum of NH_4 and NO_3 below 3 ft decreased from 50 to 18 lb ac^{-1} by year three.

Early planted rye and oats (mid in 2007) had less soil NO_3 in the surface 3 inches in all three years (Figure 2). This effect was maintained throughout the profile in 2005, but not in other years. Early planted barley exhibited a similar effect of lower surface NO_3 in two years, but not in 2005. In this year, early barley growth was especially poor. In 2006 and 2007, soil NO_3 decreased with depth for all cover crops (Figure 2).

Carbon:Nitrogen Ratio of Rye and Rye+Vetch Cover Crops

In 2006, spring N application reduced the C:N ratio of rye but not vetch or the rye+vetch combination (Table 4). This observed difference probably does not have biological significance since the ratio is still above 50:1, indicating a net nitrogen sink in the short term. No differences in C:N ratio were observed due to N application in 2007, but did vary significantly among crops. Unlike 2006 where the rye+vetch treatment was in the range of 30:1, which was between vetch alone and rye alone, in 2007 the C:N ratio of the mixture was very similar to vetch alone (Table

4). The cover crop was terminated on approximately the same calendar date in both years but dry spring conditions in 2007 limited growth with the result of less mature rye. Vetch also made up a greater proportion of the total plant material in this season.

Cover Crop Effects on Pumpkins

Figures 3 and 4 demonstrate the impact of cereal cover crops and the resulting ground cover on a following pumpkin crop.

DISCUSSION

Among cereal cover crops, rye produced the greatest biomass in our studies. In fact, even late planted rye often outyielded the other cereals even when planted early. Results from these studies as well as others demonstrating this advantage led the Virginia Department of Conservation and Recreation (VADCR) to offer a $5 per acre payment incentive for growers who plant rye, in addition to the existing cost share program.

Our research plots moved to different fields on the farm each year to match the crop rotation. Despite this, we observed a decrease in soil NO3 both prior to planting and at termination of cover crops in years two and three. The use of cereal cover crops expanded greatly on the cooperating farm over the course of the study, as the producers gained experience and observed cover crop benefits. Ultimately producers, NRCS workers, crop advisors, and others now have up-to-date and accurate local information about the most effective cover crop species and management practices for the Coastal Plain of Virginia and the mid-Atlantic.

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Table 1. Analysis of variance for cover crop yield and nitrogen uptake, 2005-2007.

		2005	
	df	Yield	N Uptake
		---------Pr>F---------	
crop	3	**	**
plant	2	**	**
crop*plant	6	ns	ns
Error A	11		
nrate	2	**	**
crop*nrate	6	ns	ns
plant*nrate	4	ns	ns
crop*plant*nrate	12	ns	ns
Error B	25		

		Yield		N Uptake	
	df	2006	2007	2006	2007
		----------------------Pr>F----------------------			
crop	5	**	**	**	**
plant	2	**	**	**	**
crop*plant	9	ns	*	ns	*
Error A	17				
nrate	1	*	**	ns	**
crop*nrate	5	ns	*	ns	**
plant*nrate	2	ns	ns	ns	ns
crop*plant*nrate	8	ns	ns	ns	ns
Error B	22				

Table 2. Cereal cover crop biomass and nitrogen uptake response to GS 25 spring nitrogen.

Year	Spring N Rate	Biomass Yield	N Uptake
	Lb ac^{-1}	Ton ac^{-1}	Lb ac^{-1}
2005	0	2.1	51
	25	3.4	80
	50	3.7	89
	LSD	0.7	17
2006	0	3.1	63
	30	3.9	85
	LSD	0.3	18
2007	0	2.2	76
	30	2.7	100
	LSD	0.2	12

Table 3. Preplant soil nitrate and ammonium nitrogen, 0-90 cm.

Year	Depth	NO_3-N	NH_4-N
	----in----	------lb ac^{-1}------	
2005	0-12	33.0	19.5
	12-24	29.4	18.2
	24-36	30.9	18.6
	LSD (0.05)	4.6	3.9
2006	0-6	25.9	13.3
	6-12	17.9	10.6
	12-24	17.9	12.2
	24-36	17.9	11.3
	LSD (0.05)	6.3	5.9
2007	0-6	19.4	2.9
	6-12	12.2	4.0
	12-24	14.7	2.4
	24-36	14.0	4.0
	LSD (0.05)	4.5	0.7

Table 4. Carbon to nitrogen ratio for rye, vetch, and rye+vetch.

		C:N Ratio	
2006	Crop	N Rate, lb ac^{-1}	
		0	30
	Rye	58	52
	Rye+Vetch	37	34
	Vetch	14	13
	LSD	3	
2007	Rye	31	38
	Rye+Vetch	12	15
	Vetch	10	11
	LSD	7	

Figure 1. Biomass yield (a) and nitrogen uptake (b) by species, 2005, biomass yield (c) and nitrogen uptake (d) by species, 2006, and biomass yield (e) and nitrogen uptake (f) by species, 2007, no spring nitrogen.

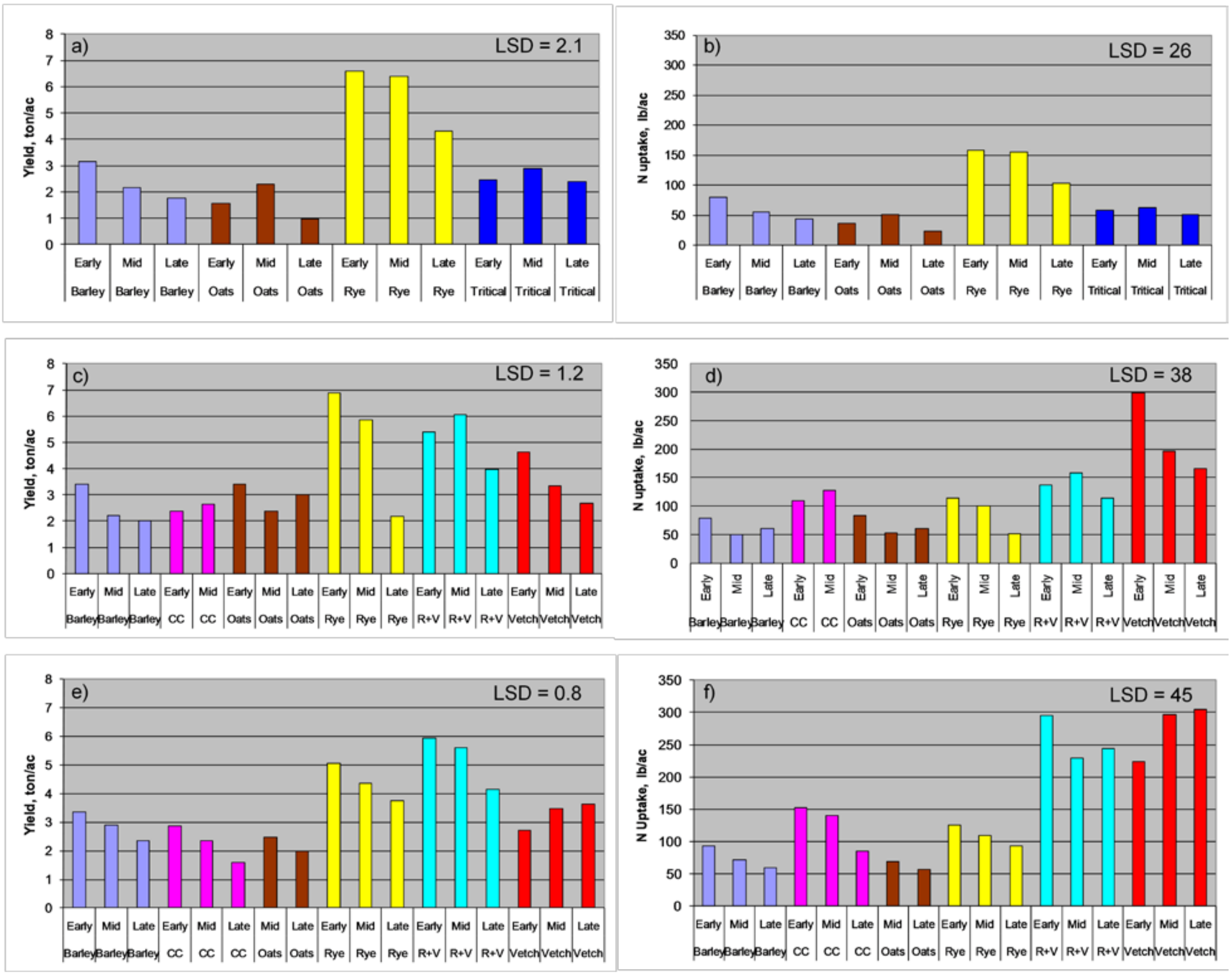

Figure 4. Soil nitrate concentration with depth for oat, barley, and rye cereal cover crops, a) 2005, b) 2006, and c) 2007.

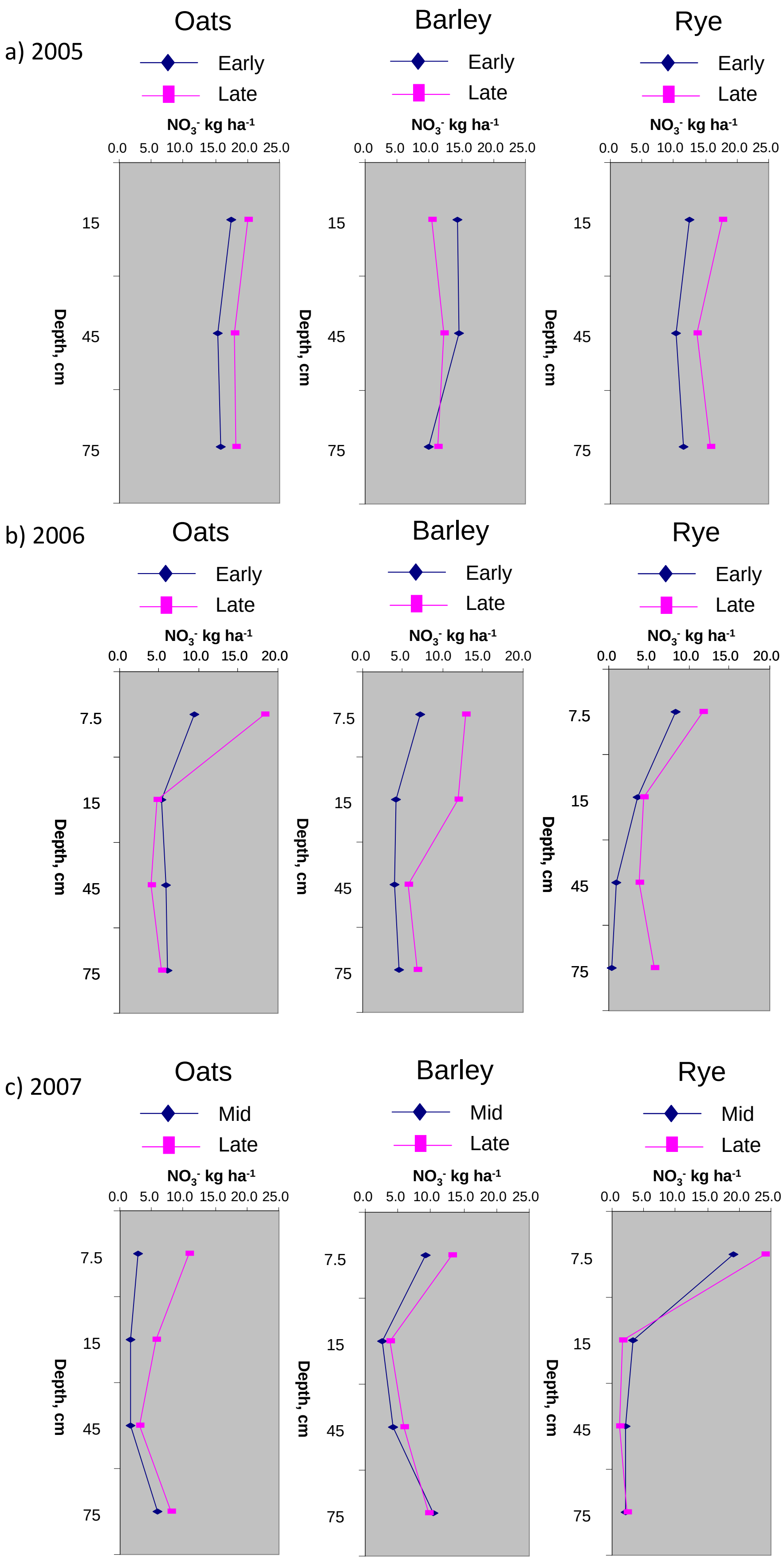

Figure 3. Ground cover present during mid-season growth of pumpkins following a) early planted rye; and b) late planted barley.

a) b)

Figure 4. Pumpkin shell quality impacts of rye cover crop.