Effects of a Grass-Selective Herbicide in a Vetch–Rye Cover Crop System on Nitrogen Management

A. J. Clark,* J. J. Meisinger, A. M. Decker, and F. R. Mulford

ABSTRACT

Cover crop kill date affects N fixation by hairy vetch (*Vicia villosa* Roth), N uptake by cereal rye (*Secale cereale* L.), residue C/N ratio, and subsequent N availability. Data are needed on spring management of vetch–rye cover crop mixtures, compared to pure stands, to estimate fertilizer nitrogen (FN) equivalents. A 2-yr study evaluated spring management of hairy vetch (HV), pure rye, a vetch–rye mixture, and a no-cover check on N accumulation and subsequent no-till corn N uptake following corn FN rates of 0, 45, 90, 180, and 270 kg ha^{-1}. A grass-selective herbicide (GSH) was applied in late March to the pure rye and the vetch–rye mixture, leaving HV to accumulate N until early May. These treatments were compared to the same covers killed in early May. Cover crop N uptake was lowest for rye, intermediate for the mixtures, and highest for HV. The N content in the pure rye and vetch–rye mixture was significantly increased if the previous year's corn had received excess FN. The cover crop mixture produced greater rye growth if fall soil nitrate N was high, while low soil nitrate N resulted in greater yield of HV in the mixture. There was no difference in corn N uptake for the late- vs. early kill pure rye, or of the rye component in the vetch–rye mixture. A vetch–rye mixture functioned like a "dual purpose" cover by conserving fall residual N, producing a lower C/N ratio residue than pure rye, and supplying more N to the succeeding corn than pure rye, although the N supplied was still less than pure vetch.

Legume cover crops function quite differently than grass cover crops. Hairy vetch has been shown to regularly supply large amounts of N for a subsequent corn crop (Ebelhar et al., 1984; Holderbaum et al., 1990; Hargrove, 1986; Clark et al., 1995, 1997a) but vetch conserves relatively little fall residual NO_3–N (Shipley et al., 1992). Cereal rye planted early in the fall (Brinsfield and Staver, 1989) has been shown to take up residual FN that can reduce winter NO_3–N leaching. Rye usually scavenges more N than other cover crops (Brinsfield and Staver, 1991; Meisinger et al., 1991; Shipley et al., 1992; Ranells and Wagger, 1997a). However, corn following small-grain cover crops often requires more FN than if no cover crop were grown (Mitchell and Teel, 1977; McCracken et al., 1989; Wagger, 1989b; Munawar et al., 1990; Eckert, 1988; Clark et al., 1997b). Maximum yield following small grain covers is often less than following legume covers (Decker et al., 1994). Vetch–rye cover crop mixtures have the potential to combine some of the advantages of both legume and grass cover crops, if properly managed. With no FN, corn yields following vetch–rye mixtures (Clark et al., 1994, 1997b) or legume–wheat (*Triticum aestivum* L.) mixtures (Holderbaum et al., 1990) were less than pure vetch, but greater than pure rye or no cover crop.

Optimizing the management of a vetch–rye cover crop mixture is complicated due to differences in spring growth of the two components. Hairy vetch can accumulate N at a rate of 2 kg N ha^{-1} d^{-1} from April to early May (Clark et al., 1994, 1997a). However, rye quickly matures during this same period resulting in a high C/N ratio that may reach 50:1 (Clark et al., 1997a) or 66:1 (Clark et al., 1994). An early kill of the mixture can lower the C/N ratio of the rye, but would limit vetch N accumulation. In contrast, a late kill of a vetch–rye mixture can result in greater vetch N accumulation. The downside of this practice is the resulting higher C/N ratio of the rye and the reduced N availability for the following crop.

Synchronization of cover crop N release with corn N uptake is also important to the success of a cover crop system. Wagger (1989a) and Vaughan and Evanylo (1998) reported that early killed rye resulted in a faster N release, while N release from vetch was similar when killed either early or late. Early kill of a vetch–rye mixture has also been reported to release N faster (Vaughan and Evanylo, 1998), but would likely sacrifice total residue production, potentially resulting in less moisture conservation (Clark et al., 1997b; Vaughan and Evanylo, 1998).

Limited data are available on N mineralization rates from cover crop mixtures. Davis et al. (1990) and Ranells and Wagger (1996) reported that the rate of N release from vetch–rye mixtures was intermediate to pure vetch and pure rye. Although more N was measured in the topgrowth of a vetch–rye mixture than in pure vetch or pure rye killed late, corn grain yield following the mixture was intermediate to pure vetch and pure rye (Clark et al., 1994, 1997a; Ranells and Wagger, 1997b). Holderbaum et al. (1990) and Ranells and Wagger (1997a) concluded that greater N immobilization was responsible for the intermediate corn yield

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Abbreviations: CKL, no-cover check; DM, dry matter; FN, fertilizer N; GSH, grass selective herbicide; HV, hairy vetch; LSD, least significant difference; MXL, late-killed vetch–rye mixed cover; MXP, early killed rye in vetch–rye mixed cover; RCB, randomized complete block; RYL, late-killed pure rye cover; RYP, early killed pure rye cover; VTL, late-killed vetch cover.

response following grass–legume mixtures, compared to the pure legume.

Data are needed on spring management of grass–legume mixtures to optimize kill-date effects and to more accurately estimate corn FN needs. Our general objective was to evaluate cover crop management practices aimed at reducing excessive rye growth, yet allowing high vetch N production. The specific objectives were to evaluate management strategies of: an early (mid-March) application of a GSH to a vetch–rye mixture or a pure rye cover, and a late-kill (early May) of all vegetation in a vetch–rye mixture, a pure rye cover, a pure vetch cover, and a no-cover control. Effects of these treatments on crop N cycling were evaluated by documenting the cover crop yield, N content, C/N ratio, and the N uptake of the succeeding corn crop receiving four rates of FN. Corn grain yield, soil moisture, and economic interpretations are presented in a companion paper (Clark et al., 2007).

MATERIALS AND METHODS

A 2-yr study (1989–1991) was conducted on a Mattapex silt loam soil (fine-silty, mixed, mesic, typic Hapludult) on the Atlantic Coastal Plain of Maryland at the Poplar Hill Research Farm, 38° N lat. Cover crop treatments of: no cover, hairy vetch, cereal rye, or a vetch–rye mixture occupied whole plots of a split-plot design with whole plots measuring 24.4 m by 3.1 m wide. Common hairy vetch was seeded at 28 kg ha^{-1}, 'Abruzzi' rye at 94 kg ha^{-1}, and the mixture seeded with 21 kg ha^{-1} vetch and 47 kg ha^{-1} rye as recommended by Clark et al. (1994). In the fall of 1989, covers were seeded into a plowed seedbed on 6 October following plow-tillage corn. Corn (Pioneer 3241) was seeded no-till into killed cover crop mulches on 12 May 1990 and 13 May 1991 in 76-cm rows running the entire length of the whole plots. Following 1990 corn harvest, the area was disked and the cover crops were re-seeded into the same whole plots on 6 October. The six whole-plot treatments were randomly assigned to their experimental units and consisted of cover crop and spring kill-date combinations of: no cover check (CKL), early killed pure rye (RYP), late-killed pure rye (RYL), early killed rye in vetch–rye mixture (MXP), late-killed vetch–rye mixture (MXL), and late-killed vetch (VTL). The two early kill treatments consisted of a single application of "Poast" {2-[1-(ethoxyimino)butyl]-5-[2(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} herbicide broadcast sprayed on 21 Mar. 1990 and 20 Mar. 1991 to kill the rye. All plots were also sprayed with a tank mixture of gramoxone (1,1′ dimethyl-4. 4-bipyridinium ion), atrazine (2-chloro-4 ethylamino-6-isopropylamino-S-triazine), cyanazine [2-chloro-4-(1-cyano-1methylethylamino)-6-ethylamino-S triazine], and 2,4-dichloronhenoxy-acetic acid on 2 May 1990 and 1 May 1991 (late kill) at recommended application rates of: (kg a.i. ha^{-1}) 0.35, 1.5, 1.6, and 0.6, respectively. The May herbicide application killed all existing cover crop vegetation and provided residual weed control for the succeeding corn crop.

Corn FN rates made up the subplots of the experimental design and were 0, 45, 90, and 180 kg N ha^{-1} for vetch; and 0, 90, 180, and 270 kg N ha^{-1} for the no-cover, rye and the vetch–rye mixture treatments. Ammonium nitrate was broadcast by hand on 22 May l990 and 31 May 1991, when corn was at the two- to three-leaf stage. The complete experimental design was a split-plot, randomized complete block, with four replicates.

Hand samples of cover crop growth were taken on all whole plots just before herbicide applications by clipping two 0.6-m square areas per plot. Mixtures were separated into vetch and rye components. Samples were dried in a forced-air oven for 72 to 96 h at 60°C, weighed for dry matter (DM) yield determination, ground to pass a 1-mm screen, and analyzed for C and N content using a Leco CHN-600 Analyzer (LECO, St. Joseph, MI). Corn N uptake was measured 20 Sept. 1990 and 17 Sept. 1991 by hand-harvesting 3.7 m of one of the two center rows. Three representative whole plants from each plot were chopped in the field, and processed by drying and grinding as outlined above for the cover crop samples.

Soil samples were taken to a depth of 90 cm after corn harvest in the fall of 1990. Six 1.9-cm diam. cores were taken per plot in 20-cm increments through 60 cm plus a final 30-cm increment from 60 to 90 cm. Soils were rapidly air-dried at room temperature, ground to pass a 2-mm screen, and mixed. Ten-gram samples of soil were extracted with 50 mL of 2 *M* KCl and analyzed for NO_3–N and NH_4–N on a Technicon Autoanalizer (Technicon Instruments, Emeryville, CA) using the Cadmium reduction method for nitrate and the indophenol method for ammonium as described by Bundy and Meisinger (1994).

Data were analyzed using SAS (SAS Institute, 1988). In 1990, cover crop data were analyzed as a randomized complete block (RCB) because prior FN treatments had been uniform over the new study area. In 1991, these data were analyzed as a split-plot, RCB, to account for the variable corn FN rate in 1990. Corn data were analyzed as a split-plot RCB. For the combined analysis over years, year was considered a fixed effect (McIntosh, 1983). Soils data were analyzed for each depth, and totaled over the 90-cm depth, using a split-plot randomized complete block analysis. Quadratic response functions were fit to the corn N uptake data using the SAS general linear models procedure.

RESULTS AND DISCUSSION

Cover Crop Yield, Nitrogen Uptake, and Soil Nitrate Content

First Year Data

Cover crop total DM yields were not significantly different for rye, vetch, or the vetch–rye mixture for the early harvest of 1990 (Table 1). However, total N content of the rye was significantly lower in mid-March. Total N content of the mixture (MXP) was not significantly lower than pure vetch, although only 70% of the N in the mixture was from the vetch.

On the late-kill date, DM ranged from 5690 kg ha^{-1} for vetch to 2370 kg ha^{-1} for rye that had been killed early (Table 1). The highest N content was for vetch, the lowest for rye, and the mixtures (MXP or MXL) were intermediate. This contrasts with earlier results of Clark et al. (1997a), Teasdale and Abdul-Baki (1998), and Ranells and Wagger (1997c) who reported somewhat higher total N contents in vetch–rye mixtures than in pure vetch. There was no difference in total N content for rye killed early vs. rye killed late, and there was no difference in the total N content of the mixture when rye was killed early (MXP) or killed late (MXL). It appears that the rye had reached maximum N uptake by late March with little or no measurable N taken up during

Table 1. Cover crop DM yield (kg ha^{-1}) and N content (kg N ha^{-1}) as influenced by fall planting of pure vs. mixed grass–legume seedings and by spring cover crop kill date.

Cover crop treatment			Harvested 21 Mar. 1990			Harvested 2 May 1990		
Crop species	Kill date	Treatment code†	Total	Rye	Vetch	Total	Rye	Vetch
			DM yield, kg ha^{-1}					
Vetch–rye	early	MXP	3130	1480	1650	3840	2400	1440
Vetch–rye	late	MXL	–	–	–	4870	3040	1830
Vetch	late	VTL	2980	–	2980	5690	–	5690
Rye	early	RYP	2410	2410	–	2370	2370	–
Rye	late	RYL	–	–	–	4670	4670	–
Statistics: LSD(0.05)			ns	ns	313	1039	783	542
			N content, kg N ha^{-1}					
Vetch–rye	early	MXP	98	29	69	121	29	92
Vetch–rye	late	MXL	–	–	–	122	29	92
Vetch	late	VTL	104	–	104	179	–	179
Rye	early	RYP	37	37	–	35	35	–
Rye	late	RYL	–	–	–	37	37	–
Statistics: LSD(0.05)			18	ns	9	14	6	14

† MXP is vetch–rye mixture killed late March, MXL is vetch–rye mixture killed early May, VTL is vetch killed early May, RYP is rye killed late March, and RYL is rye killed early May.

April. The rye may have accumulated most of the available N by this time, or it could be the result of N leaching below the root zone due to above average rainfall of 150 mm in April (Fig. 1). Earlier research at this research site (Shipley et al., 1992; Clark et al., 1997a) also reported little or no accumulation of rye N during April. Nitrogen uptake was not significantly greater for pure rye (37 kg ha^{-1}) than for the rye component of the mixture (29 kg ha^{-1}). The vetch N production in the mixture was not increased when the rye component was killed early (92 kg vetch N ha^{-1} for MXP or MXL). However, the pure vetch produced more N than the vetch in the mixture, regardless of when the rye component was killed.

The C/N ratio of the covers was 28 for early killed rye, 57 for late-killed rye, 13 for early killed rye in the mixture (MXP), 17 for late-killed rye in the mixture, and 11 for the vetch (LSD 0.05 = 4, data not shown). These C/N ratios suggest a likely net immobilization of N (C/N > 25) from the pure rye cover crop residues even when it was killed early. A net N mineralization would be likely from the vetch or vetch–rye mixture

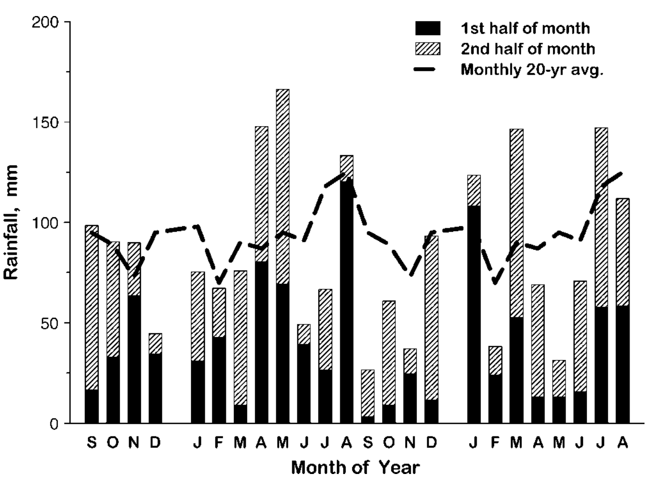

Fig. 1. Twenty-year average monthly rainfall at Poplar Hill research station and monthly rainfall distributions during the study period of September 1989 to August 1991.

residues (C/N < 20), according to Allison (1966). Other research (Vaughan and Evanylo 1998; Ranells and Wagger 1996; Clark et al., 1994) has reported similar trends in C/N ratios for rye, hairy vetch, and vetch–rye mixtures. Corn N uptake data discussed below demonstrates greater N availability to unfertilized corn following the mixture or the vetch than for corn following rye or no-cover crop.

The 90-cm deep soil samples collected at the end of the 1990 corn season showed significant treatment effects on soil NO_3–N levels, but no significant effect on soil NH_4–N levels. Therefore, the low quantities of soil NH_4–N are not presented. Within cover crop, soil NO_3–N increased with each increment of FN applied to the preceding corn crop (Table 2). With the exception of RYL, residual soil NO_3–N was low (17–38 kg NO_3–N ha^{-1}) for nonfertilized treatments, moderate (38–67 kg NO_3–N ha^{-1}) for the first increment of FN, and greatest (85–141 kg NO_3–N ha^{-1}) for the highest FN rate. The low residual NO_3–N following RYL at all rates of corn FN probably reflects continued N immobilization caused by the high C/N rye residue, while the higher levels of residual N following vetch or mixtures reflect excess N from the combination of FN plus large amounts of N from the legume. High levels of fall residual N following surplus inputs of FN and drought have also been reported by Ranells and Wagger (1997c). The highest rate of FN for each cover crop treatment (180 kg ha^{-1} for vetch, or 270 kg ha^{-1} for the others) did not result in significantly greater grain yield in 1990 (Clark et al., 2007). Thus, the high residual N levels were due to surplus inputs from corn FN and cover crop N. These varying levels of fall residual NO_3–N set the stage for growth effects on the 1990 fall-seeded cover crops.

Second Year Data

Cover crop yield and N content in 1991 were significantly affected by the previous year's cover crop and corn FN rates (Tables 2 and 3). The whole-plot treatments of cover crop species or kill date were significant for DM and total N content. The interaction of whole-

Table 2. Soil nitrate N to 90 cm (kg N ha^{-1}) in the fall of 1990 and cover crop DM yield (kg ha^{-1}) on two harvest dates in the spring of 1991 as influenced by the 1990 cover crop treatments and the 1990 corn fertilizer N rates.

			Harvested 20 Mar. 1991			Harvested 1 May 1991		
Cover crop treatment†	1990 corn FN rate	1990 fall residual NO_3–N	Total	Rye	Vetch	Total	Rye	Vetch
	kg N ha^{-1}		DM yield, kg ha^{-1}					
Vetch–rye, early kill, "MXP"	0	27	930	630	300	6330	1380	4950
	90	–	970	750	220	5760	1420	4340
	180	54	1050	910	140	6520	2480	4040
	270	91	1300	1150	150	5560	2460	3100
Means	–	57	1060	860	200	6040	1930	4110
Vetch–rye, late kill, "MXL"	0	23	–	–	–	6730	2530	4200
	90	–	–	–	–	8450	4620	3830
	180	64	–	–	–	9260	5390	3870
	270	141	–	–	–	10550	8650	1900
Means	–	76	–	–	–	8750	5300	3450
Vetch, late kill, "VTL"	0	38	–	–	–	5610	–	5610
	45	–	–	–	–	5290	–	5290
	90	53	–	–	–	4890	–	4890
	180	123	–	–	–	5470	–	5470
Means	–	71	–	–	–	5320	–	5320
Rye, early kill, "RYP"	0	26	360	360	–	2010	2010	–
	90	–	450	450	–	2170	2170	–
	180	67	640	640	–	2860	2860	–
	270	85	930	930	–	4810	4810	–
Means	–	59	600	600	–	2960	2960	–
Rye, late kill, "RYL"	0	17	–	–	–	3160	3160	–
	90	–	–	–	–	3020	3020	–
	180	38	–	–	–	3810	3810	–
	270	45	–	–	–	3930	3930	–
Means	–	33	–	–	–	3480	3480	–
Statistics, LSD (0.05)								
Cover crops		19	266	269	269	727	720	667
Cover crops × FN		45	ns	ns	ns	1563	1379	1088

† MXP is vetch–rye mixture killed late March, MXL is vetch–rye mixture killed early May, VTL is vetch killed early May, RYP is rye killed late March, and RYL is rye killed early May.

plot treatment by corn FN rate was also significant for the late-kill date. Fertilizer N applied to the previous corn crop increased rye DM yield and N content when seeded alone or with vetch in a mixture. The yield of vetch in pure stand was not significantly affected by previous corn FN rate, which is consistent with the results of Ranells and Wagger (1997c). The effect of previous corn FN on rye was evident for both early and late kill and represents a typical growth response of a grass to available N. Similar growth responses of rye to high residual N have been reported by Shipley et al. (1992) and Ranells and Wagger (1997c). Rye growth and yield in the vetch–rye mixture increased with increasing residual N, but this resulted in less growth of vetch. Consequently, vetch DM and N proportions in the mixture decreased as the rate of corn FN increased. Higher residual fall N for the mixtures resulted in a higher yield of rye in the mixture than after pure rye, where residual N was lower the previous fall. The yield of rye in MXL was greater than that of RYL, despite the lower rye seeding rate. Residual soil N was higher for MXL than for RYL, and the extra N and late-kill date allowed ample time for rye tillering, growth, and N uptake. Average DM yield and N content of pure vetch was greater than the vetch component in early or late-killed mixtures. In the RYP and MXP treatments, rye DM continued to increase after the March herbicide application, apparently because the winter-hardened rye crop was killed very slowly by the GSH. Dry matter yields on 1 May were greater following high corn FN rates, indicating that rye continued to take up N after the targeted 20 March kill date.

For the late-kill date, the significant cover crop by corn FN rate interaction for total DM yield can be attributed to no change in vetch yield at different FN rates, but a large increase in DM yield of cover crops containing late-killed rye. The GSH applied to the mixture produced a smaller rye yield response to corn FN (from 1380 to 2460 kg ha^{-1}) than the late-kill mixture where yields increased from 2530 kg ha^{-1} without previous FN, to 8650 kg ha^{-1} at the high corn FN rate.

For both mixtures, as corn FN increased, rye DM yield increased and vetch decreased from 4950 to 3100 kg ha^{-1} for MXP, and 4200 to 1900 kg ha^{-1} for MXL. Using the GSH on the vetch–rye mixture (MXP) allowed more vetch DM to be produced than if the rye was allowed to grow until early May (MXL).

The N content of the covers (Table 3) was also influenced by previous cover crops and corn FN rates, although some noteworthy differences occurred. There were generally no significant differences in N content of the vetch in either mixture treatment, except for the high FN rate of MXL that contained only 73 kg ha^{-1} compared to 124 kg ha^{-1} for the high FN vetch in MXP. The cover crop vegetation in the high residual N mixture that was allowed to grow until the late-kill data (MXL) contained 47% of its total N in the vetch component, while the corresponding value for the early kill mixture was 76%. Controlling rye growth early with the GSH allowed the vetch to accumulate more N than when it was competing with the rye. This difference in composition of the mixture was also reflected in the corn N uptake (below) and in the corn grain yields the following year (Clark et al., 2007).

Table 3. Soil nitrate N to 90 cm (kg N ha^{-1}) in the fall of 1990 and cover crop total N uptake (kg N ha^{-1}) on two harvest dates in 1991 as influenced by the 1990 cover crop treatments and the 1990 corn fertilizer N rates.

			Harvested 20 Mar. 1991			Harvested 1 May 1991		
Cover crop treatment†	1990 corn FN rate	1990 fall residual NO_3–N	Total	Rye	Vetch	Total	Rye	Vetch
	kg N ha^{-1}		total N uptake, kg N ha^{-1}					
Vetch–rye, early kill, "MXP"	0	27	25	10	15	206	24	182
	90	–	22	12	10	204	24	180
	180	54	22	15	7	204	38	166
	270	91	27	20	7	163	39	124
Means	–	57	24	14	10	194	32	163
Vetch–rye, late kill, "MXL"	0	23	–	–	–	219	28	191
	90	–	–	–	–	187	43	144
	180	64	–	–	–	197	46	151
	270	141	–	–	–	155	82	73
Means	–	76	–	–	–	190	50	140
Vetch, late kill, "VTL"	0	38	–	–	–	213	–	213
	45	–	–	–	–	207	–	207
	90	53	–	–	–	189	–	189
	180	123	–	–	–	195	–	195
Means	–	71	–	–	–	201	–	201
Rye, early kill, "RYP"	0	26	5	5	–	31	31	–
	90	–	7	7	–	31	31	–
	180	67	10	10	–	40	40	–
	270	85	15	15	–	64	64	–
Means	–	59	9	9	–	42	42	–
Rye, late kill, "RYL"	0	17	–	–	–	26	26	–
	90	–	–	–	–	26	26	–
	180	38	–	–	–	33	33	–
	270	45	–	–	–	29	29	–
Means	–	33	–	–	–	29	29	–
Statistics, LSD(0.05)								
Cover Crops		19	8	ns	ns	18	8	24
Cover Crops × FN		45	6	ns	ns	ns	15	ns

† MXP is vetch–rye mixture killed late March, MXL is vetch–rye mixture killed early May, VTL is vetch killed early May, RYP is rye killed late March, and RYL is rye killed early May.

Corn Nitrogen Uptake

Rainfall Distribution

Corn N uptake, in this nonirrigated study, was influenced by summer rainfall distributions. The rainfall patterns differed somewhat between 1990 and 1991 (Fig. 1). In 1990, April and May were very wet but June and July were below normal, although the total rainfall from April through August was close to the 20-yr average. In 1991, April, May, and June rainfall was below normal followed by an above-normal July. The rainfall pattern in both years was quite ample for good corn growth due to the absence of prolonged dry periods.

Corn N uptake, calculated as N concentration of silage DM yield at grain harvest, is often a more sensitive indicator of N availability than corn grain yield. Average N uptake was 30 kg ha^{-1} greater in 1991 than in 1990, attributed to better July rainfall. In 1990 (Fig. 2a), corn N uptake for CKL without FN indicated soil N availability of about 71 kg ha^{-1}. The N uptake curve for both rye treatments with 90 kg FN ha^{-1} is displaced to the right of the control curve by about 20 kg N ha^{-1}, indicating a lowered N availability of about 15 to 30 kg of the FN, but this lower availability was not significant above 180 kg FN ha^{-1}. In 1991, N uptake by CKL without FN indicated soil N availability of about 87 kg N ha^{-1}. The higher value in 1991 is probably attributable to better rainfall distributions that promoted higher soil organic N decomposition and/or lower N losses (Fig. 2b). Corn N uptake by the two rye treatments indicated about the same amount of N immobilization as in 1990 for the first 90 kg FN applied, i.e., about 15 to 30 kg N ha^{-1}. Early GSH treatment of the pure rye plots did not have a marked impact on corn N uptake.

The corn N uptake following vetch–rye mixtures was generally between pure vetch and pure rye, consistent with previously published results (Clark et al., 1997a, 1994). However, the corn N uptake of the unfertilized mixtures was closer to that of vetch than rye, because the mixture contained most (75–90%) of its vegetative N as vetch at the low FN rates. With the highest rate of FN, especially in 1991, the rye component of the MXL treatment increased to about 50% and the MXL cover supplied similar quantities of N to the corn as the pure rye cover. The effect of early GSH treatment (MXP vs. MXL) resulted in somewhat more N availability to the corn at the highest FN rates, however, when averaged over the 2 yr, the size of this benefit was only about 25 kg N ha^{-1}.

Corn N uptake from the vetch cover crop was typical of results reported in earlier studies (Decker et al., 1994; Clark et al., 1994, 1997a). The vetch N response curve was offset to the left of the control plot N uptake curve by about 100 to 140 kg N ha^{-1}, which agrees with the average vetch FN equivalent of about 155 kg N ha^{-1} reported by Seo et al. (2000). There were also indications of higher maximum N uptakes with vetch that could not be completely explained by FN additions. This has also been observed in earlier studies (Decker et al., 1994; Clark et al., 1994). The exact nature of these benefits has not been documented but can likely be attributed to surface "mulching effects" of water conservation and lower temperature, or reduced disease and insect pressure due to "rotational effects" resulting

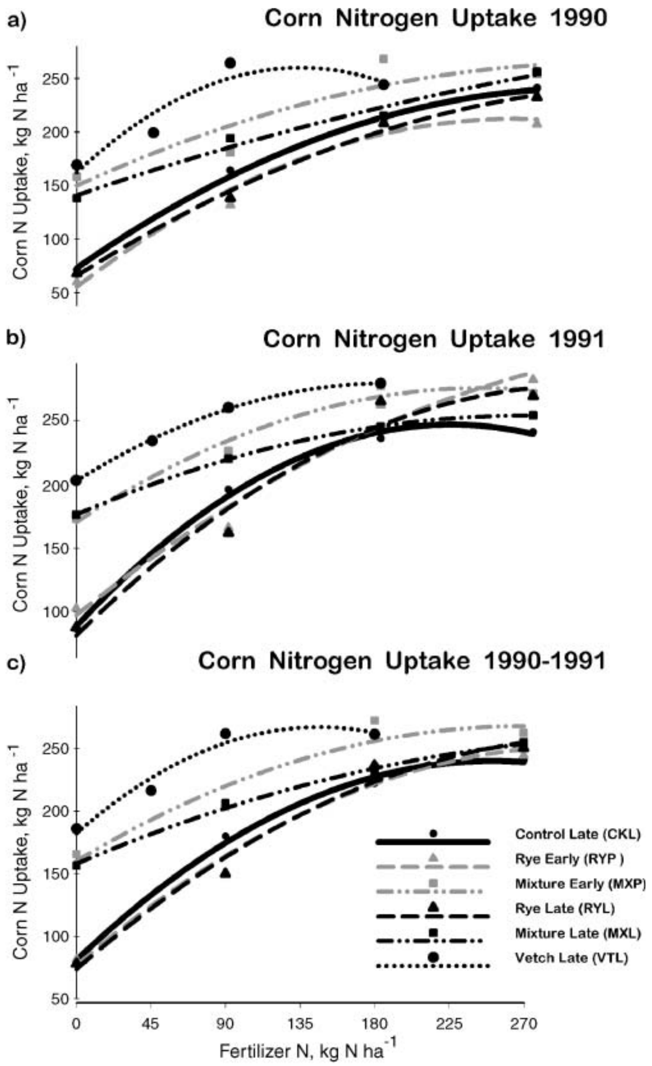

Fig. 2. Corn N uptake (kg N ha^{-1}) in 1990 (2a), 1991 (2b), and 1990–1991 average (2c) after cover crops of: rye killed early (RYP) or late (RYL), vetch killed late (VTL), vetch–rye mixture killed early (MXP) or late (MXL), or no cover (CKL).

from the break in grass monoculture. The companion paper in this series (Clark et al., 2007) documents some of the water conservation benefits of these cover crops.

The corn N uptake response over the 2 yr of this study (Fig. 2c) clearly demonstrates that N availability to corn was greatest following hairy vetch, least following rye, and intermediate following the vetch–rye mixture. The FN equivalents of the cover crops in this study can be estimated from Fig. 2c at about 100 to 140 kg N ha^{-1} for hairy vetch, 60 to 80 kg N ha^{-1} for vetch–rye mixtures, and a FN debit of about 15 to 30 kg N ha^{-1} for cereal rye. The early application of a GSH to the rye and vetch–rye mixtures did not have a marked impact on the corn N uptake curve.

CONCLUSIONS

The data of this study demonstrate that a vetch–rye cover crop mixture has the potential to function as a "dual purpose" cover crop. The rye component serves to conserve fall residual N, especially when residual N levels are high, and the vetch component serves to supply N to the subsequent corn crop. The botanical composition of the mixture is responsive to residual soil N levels and this simplifies cover crop selection for optimizing N management. The use of a GSH to control rye growth was most successful in vetch–rye mixtures and resulted in a mixture containing more desirable traits, such as a narrow C/N ratio and a greater proportion of vetch within the mixture. The N availability to corn (in FN equivalents) was greatest following hairy vetch (100–140 kg N ha^{-1}), least following rye (debit of 30 kg N ha^{-1}), and intermediate following the vetch–rye mixture (60–80 kg N ha^{-1}). The early treatment of the rye and vetch–rye mixtures with a GSH did not have a marked impact on corn N uptake. The GSH was most useful in changing the botanical composition of the vetch–rye mixture at high levels of residual N.

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