Published February 1, 2018

Nitrogen Contribution from Winter-Killed Faba Bean Cover Crop to Spring-Sown Sweet Corn in Conventional and No-Till Systems

Fatemeh Etemadi, Masoud Hashemi,* Omid Zandvakili, Aria Dolatabadian, and Amir Sadeghpour

ABSTRACT

The N release trend of winter-killed faba bean (*Vicia faba* L.) residues has not been previously investigated. A 2-yr experiment was conducted in 2013–2015 to investigate potential N accumulation in fall-grown faba bean as cover crop and N contribution to subsequent sweet corn under no-till (NT) and conventional tillage (CT) systems. Faba bean biomass prior to winter-kill was reduced linearly with delayed planting. The amount of reduced biomass estimated approximately 180 and 210 kg ha^{-1} d^{-1} in 2013 and 2014, respectively. Faba bean sown on 1 August accumulated as much as 192 kg N ha^{-1} vs. 67 kg N ha^{-1} when planted on 14 August. Under CT, 50% of N was released from residues by the end of May however NT system delayed 50% N release until end of June, thus providing better synchrony with N uptake by sweet corn. Averaged over two years, sweet corn planted into the residues of the earliest sown faba bean produced 19% more marketable ears, 23% higher fresh ear weight, and 39% less unfilled ear tip compared with sweet corn grown in plots lacking a prior faba bean cover crop. Both number of marketable ears and fresh ear yield of sweet corn were significantly higher in NT compared with CT systems. On average, sweet corn seeded in faba bean residues and amended with an additional 50 kg N ha^{-1}, yielded similarly to sweet corn received 100 kg N ha^{-1} with no prior faba bean cover crop.

Core Ideas

- Faba bean cover crops sown on 1 August accumulated up to 192 kg N ha^{-1}.
- Better synchrony between faba bean residue decomposition and N uptake by sweet corn was achieved under NT management.
- Sweet corn yielded higher under NT vs. CT system.
- On average, faba bean provided approximately 50 kg ha^{-1} of subsequent sweet corn N requirements.

Published in Agron. J. 110:455–462 (2018)
doi:10.2134/agronj2017.08.0501

Legumes can potentially replace, or significantly contribute to, the N fertilizer requirements of N demanding crops such as sweet corn (Zandvakili et al., 2012; Jahanzad et al., 2014; Hardarson and Atkins, 2003; N'Dayegamiye et al., 2015). Additionally, grain legumes serve as an excellent protein source in human and livestock diets (Huang et al., 2016; Ito et al., 2016). Faba bean is known as one of the oldest crops in the world, and it is the third most important grain legume after soybean [*Glycine max* (L.) Merr.] and pea (*Pisum sativum* L.) (Mihailovic et al., 2005; Daur et al., 2011; Singh et al., 2013). However, faba bean is not currently grown as a cover crop, mainly due to its large seed size and relatively low biomass production that makes it non-competitive compared with other legume cover crops (Etemadi et al., 2017).

Diverse ecosystem services are expected from growing faba bean (Kőpke and Nemecek, 2010), and in recent years increasing attention has been given to using faba bean as a multi-purpose legume cover crop (López-Bellido et al., 2005; Etemadi et al., 2015; Landry et al., 2015) as well as in intercropping systems (Zhang et al., 2004; Song et al., 2007; Li et al., 2009). Arguably, the most important contribution of faba bean to agricultural ecosystems is the substantial amount of atmospheric N that can be fixed by the crop and its associated rhizobia. Depending on the growing conditions, faba bean is reported to fix up to 160 kg N ha^{-1} (Cline and Silvernail, 2002; Hoffmann et al., 2007; Horst et al., 2007). For this reason, faba bean can be considered as one of the most efficient N-fixing cool-season legumes (Herridge et al., 1994). Interestingly, faba bean maintains its N-fixing capabilities, even in soils that are rich in N (Peoples et al., 2009; Kőpke and Nemecek, 2010). Other benefits and potential uses for faba bean include the following: (i) break crop in a broader rotational program (Kőpke and Nemecek, 2010; Abera et al., 2015; Landry et al., 2015), (ii) feed source for pollinators and beneficial insects (Somerville, 2002; Etemadi et al., 2015), (iii) enhanced soil microbial activity (Wang et al., 2007; Van der Putten et al., 2013; Wahbi et al., 2016), (iv) control of soil-borne diseases (Jensen et al., 2010), and (v) a rich source of L-Dopa for medicinal use (Etemadi et al., 2017). Therefore,

F. Etemadi, M. Hashemi, and O. Zandvakili, Univ. of Massachusetts, 201 Natural Resource Way, Bowditch Hall, Amherst, MA 01003; A. Dolatabadian, Univ. of Western Australia, School of Biological Sciences, Perth, Western Australia, 6009, Australia; A. Sadeghpour, Dep. of Plant, Soil, and Agricultural Systems, Southern Illinois Univ. of Carbondale, College of Science, Carbondale, IL 62901.
Received 30 Aug. 2017. Accepted 5 Jan. 2018.
*Corresponding author (masoud@umass.edu).

Abbreviations: ANOVA, analysis of variance; CEC, cation exchange capacity; CT, conventional till; GDD, growing degree days; LSD, Least Significant Difference; NT, no-till.

integrating faba bean into cropping systems as either a cover crop or a dual purpose cash/cover crop can enhance the sustainability and resiliency of agricultural production systems.

In the northeast United States, unlike many common legumes such as peas, lentils, and beans, faba bean continues its growth and fixation of atmospheric N until winter-kill in early to mid-December (Etemadi and Hashemi, 2014). Griffin et al. (2000) stated that in northern climates, legume cover crops seeded after the main crop's harvest has limited opportunity for accumulating considerable amount of biomass. When grown solely as a cover crop, faba bean can be sown as late as early September; however, pod harvest opportunity is unlikely in late planting. Earlier planting of faba bean results in greater biomass production and root activity, and thus provides more ecological services, including increased N contributions to the subsequent cash crop (Song et al., 2007; Kőpke and Nemecek, 2010). Growing dual-purpose faba bean as a cash and cover crop requires an earlier sowing in July (unpublished data).

In New England, sweet corn is cultivated on 5540 ha (National Agricultural Statistics Service, 2014), and is one of the most widely grown vegetable crops. Like other types of corn, sweet corn is considered a high N demanding crop, requiring 130 to 160 kg N ha^{-1} on average (University of Massachusetts, 2016). Nitrogen utilization efficiency can be substantially improved by including legume cover crops in cropping systems, and also by improving the synchronization of N inputs and uptake sinks (Essah and Delgado, 2009). A previous report suggested that faba bean as green manure can significantly lower the cost of N fertilizer and the crop may also offer additional soil health benefits (Kőpke and Nemecek, 2010).

In southern New England, active decomposition of winter-killed cover crops, including fall-grown faba bean, generally begins as early as mid-March. However, sweet corn is commonly planted in mid-May. In contrast to winter-killed faba bean, spring-grown faba bean residues generally have a significantly lower C/N ratio that causes the N mineralization of the residues to occur much faster (Shi, 2013). This fast rate of decomposition may not be well synchronized with the N uptake pattern of the following crop, which results in a higher risk of N loss to the environment (Jensen et al., 2010), especially in CT systems. Improving the synchrony of N release from faba bean residues can enhance the N uptake/utilization efficiency of the succeeding crop, thus reducing potential environmental hazards (Thompson et al., 2015). The C/N ratio of cover crop residues is an important functional trait that influences the subsequent crop yield (Kuo and Sainju, 1998; Starovoytov et al., 2010).The C/N ratio can be manipulated by mixing legume and non-legume cover crop species (Teasdale and Abdul-Baki, 1998; Finney et al., 2016). For example, a mixed vetch and winter rye cover crop may supply sufficient, timely N to NT field corn (Griffin et al., 2000; Cline and Silvernail, 2002). Mixing faba bean with a grass companion cover crop has been suggested to balance its C/N ratio (Ranells and Wagger, 1997; Villamil et al., 2006). However, when faba bean is grown as a dual-purpose cash and cover crop, the use of a companion grass with faba bean is not practical. Implementing a NT system in which winter-killed faba bean residues remain on the soil surface may be a viable option to slow down the N mineralization rate in the spring, thus providing improved synchrony with N uptake of sweet corn. Moreover, an integrated cover crop and NT system is an effective strategy to build soil organic matter (Sainju et al., 2002).

There is a need for a better understanding of the trend of N release from winter-killed faba bean residues. We hypothesized that leaving fall-sown faba bean cover crop residues on the soil surface would provide a better N release/uptake synchrony with spring-sown sweet corn as opposed to incorporating the faba bean residues into the soil. Therefore, the main goals of the current study were to:

1. Evaluate the decomposition trend of winter-killed faba bean residues in CT and NT systems.
2. Assess the contribution of faba bean residues to the N demand of succeeding sweet corn.

MATERIALS AND METHODS

Experimental Site and Weather Conditions

A 2-yr experiment was conducted in 2013–2015 at the University of Massachusetts Amherst Agricultural Experiment Station Crops and Animal Research and Education Farm in South Deerfield, MA (42°28¢37″ N, 72°36¢2″ W). The soil type at the experimental site was a Hadley fine sandy loam (nonacid, mesic Typic Udifluvent). Composite soil sample (0- to 0.2-m depth) taken prior to planting indicated soil pH (1:1, soil/H_2O) was 6.6, cation exchange capacity (CEC) was 8.1 meq 100 g^{-1}, and available P, K, and Mg were all in the optimum range, thus no fertilizer was applied to the experimental plots in either year. Due to the humid northeastern climate, N recommendations are not based on specified soil nitrate test results (Lawrence et al., 2008). Weather conditions including growing degree days (GDD), precipitation throughout the experiment period (2013–2015), and the norm (average of 20 yr), for the region are presented in Table 1.

Experimental Setup, Treatments, and Field Operations

The experiment was laid out as split-plot arrangement within a randomized complete block design with four replications at the same experimental units as the previous year. Main plots consisted of NT and CT treatments. Sub-plots were allocated to a factorial combination of three faba bean planting dates (1, 7, and 14 August) and no cover crop (control) with supplemental N rates (0, 25, 50, 75, and 100 kg N ha^{-1}) applied to sweet corn the following spring. Individual sub-plots consisted of three rows, 4.2 m long and 0.76 m wide. Faba bean 'Windsor' was planted with a plot grain drill at a density of 8.8 plant m^{-2}. Seeds were inoculated with peat base *Rhizobium leguminosarum* (N-Dure, Verdesian, Cary, NC) before sowing in both years. No irrigation was used in this experiment as irrigation is not a common practice for agronomic field crops in Massachusetts. Faba bean biomass was determined prior to winter-kill (roughly mid-December in both years) by harvesting 1 m^2 from all plots.

In the spring, faba bean residues were disked into the soil in the CT plots. Residues remained on the soil surface in the NT treatment. An early maturity sweet corn (Spring Treat F1 (se) Nat II, 66 d) was planted on faba bean stubble rows on 15 May in both years at a population density of 65,000 plants ha^{-1}.

Table 1. Precipitation and accumulated GDD during growing seasons of faba bean (2013 and 2014), sweet corn (2014 and 2015), and faba bean residues decomposition (2014 and 2015) compared with 20 yr average of corresponding months for the experimental location.

	GDD†			Precipitation		
Month	2013	2014	Norm	2013	2014	Norm
				——— mm ———		
Faba bean						
Aug.	858	835	907	99	92	91
Sept.	591	630	643	77	41	109
Oct.	316	368	286	67	160	110
Nov.	68	45	89	94	90	77
Dec.	10	11	16	81	116	79
Total	1843	1889	1941	418	499	466
No crop	2014	2015	Norm	2014	2015	Norm
Jan.	9	0	3	82	83	67
Feb.	0	0	2	59	37	69
Mar.	3	2	47	82	43	95
Apr.	167	157	204	112	51	80
Total	179	159	256	335	214	311
Sweet corn	2014	2015	Norm	2014	2015	Norm
May	516	674	515	29	26	88
June	785	715	767	1	192	116
July	947	938	942	55	85	98
Total	2248	2327	2224	84	303	302

† GDD calculated as GDD = $\sum (T_{max} - T_{min})/2 - T_b$ where T_{max} and T_{min} are daily maximum and minimum temperatures, respectively. Base temperature (T_b) was set as 4 and 10°C for faba bean and sweet corn, respectively.

Nitrogen fertilizer in the form of calcium ammonium nitrate (27% N) was side dressed to sweet corn at 0, 25, 50, 75, and 100 kg N ha^{-1} within each faba bean cover crop date of planting.

In faba bean plots, weeds were controlled mechanically (by hand and rototiller) three times during its growing period. Weed control in sweet corn was similar in both years and consisted of 2.2 kg a.i. ha^{-1} dual magnum (2-chloro-2',6'-diethyl-*N*-(methoxymethy1)-acetanilide, and 1.8 kg a.i. ha^{-1} treflan (*a,a,a*-trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine) pre-emergence herbicide.

Sweet corn ears from center rows were hand harvested on 6 Aug. 2014 and 10 Aug. 2015 at peak marketable stage. The marketable ear number (minimum of 17 cm in length), ear fresh yield, and percentage of unfilled ear tip were determined.

Faba Bean Residues Decomposition

A mesh bag technique was used based on the procedure fully described by Jahanzad et al. (2016). Mesh bags (60 µm) were made of polyamide nylon with a finished size of 20 × 10 cm. Prior to winter-kill, 10 faba bean plants were dug out carefully, washed, and air dried. Total fresh biomass including roots and shoots were determined. The tissue samples were dried in a forced air oven at 80°C for 36 h. Dried samples were weighed, then ground fine to pass through a 0.42-mm screen. A 200-mg subsample was used for N analysis. A Kjeldahl method of digestion (potassium sulfate, cupric sulfate, sulfuric acid) was used, followed by N measurement with a Lachat 8500 FIA spectrophotometer, Lachat Method no. 13-107-06-2-D (Zellweger Analytical, Milwaukee, WI).

Eighty mesh bags were filled with 200 g of uniformly mixed fresh chopped plant tissues. Forty mesh bags were left on the soil surface (simulating NT system) and 40 bags were buried 20 cm deep in the soil (simulating CT system). Three mesh bags, representing three replications, were recovered from both tillage systems on a weekly basis beginning 1 April. At each retrieval time, the content of each bag was dried in a forced-air oven set at 70°C, ground, weighed, and analyzed for dry matter and N content.

Statistical Analysis

Analysis of variance (ANOVA) was conducted with the mixed model procedures in SAS (SAS Institute, 2003). Data shown in figures are the arithmetic means of four replicates of each treatment. Mesh bag retrieval dates were a continuous array of treatments, so trends in cover crop residue dry matter and N release during decomposition were assessed by regression analysis. Effects were considered significant at $P \leq 0.05$ by the *F* test, and when the *F* test was significant, Fisher's Least Significant Difference Test (LSD) was used for mean separation.

RESULTS AND DISCUSSION

Weather

Cumulative growing degree days (GDD$_4$°C) at Orange Airport, MA (roughly 27 km away from the research site), during the growth period of faba bean cover crop (August–December), were 1843 and 1889 in 2013 and 2014, respectively, which were lower than the norm for this location (Table 1). Cumulative GDD during the months of May through August when sweet corn normally grows in New England were similar to the norm for the location in both years of the study. From August to December, months that spanned the faba bean growth period, precipitation totaled 418 mm in 2013 and 499 mm in 2014, which were comparable to the norm for the area. However, in spring 2014, the sweet corn crop experienced an unusual drought condition throughout the entire growing season (Table 1). Therefore, when averaged across all faba bean planting dates, the sweet corn yielded roughly 15% less overall in 2014 than in 2015. The influence of year and the interaction of year by trait were significant; accordingly, the results of the 2 yr are presented separately.

Cover Crop Biomass and Decomposition Trend

Faba bean biomass just prior to winter kill was dramatically influenced by date of planting (Table 2). The key benefit of legume cover crops is their role in supplying significant amounts of atmospheric N to a successive crop. However, it is well documented that the magnitude of agronomic services from cover crops in general, and N contribution from legumes in particular, are largely dependent on the amount of biomass they can produce by the termination time (Snapp et al., 2005; Hashemi et al., 2013; Finney et al., 2016; Mirsky et al., 2017). Early planting has been recognized as one major factor that influences cover crop biomass yield (Hashemi et al., 2013; Lounsbury and Weil, 2014; Komainda et al., 2016). In the current study, faba bean biomass decreased linearly as planting date was delayed. The amount of biomass loss for each day of delay was significant and estimated around 180 and 210 kg ha^{-1} in 2013 and 2014, respectively. However, the first week of planting delay (8 August vs. 1 August) was responsible for only a 19 and 7% biomass reduction in 2013 and 2014, respectively. Conversely, the second week of planting

Table 2. Faba bean biomass and N concentration in faba bean aerial biomass prior to winter kill as influenced by its date of planting.

Faba bean	Biomass		N in residues		N yield	
Planting date	2013	2014	2013	2014	2013	2014
	—— Mg ha^{-1} ——		—— g kg^{-1} ——		—— kg ha^{-1} ——	
1 Aug.	4.0 ± 0.1	5.3 ± 0.1	25 ± 0.2	36 ± 0.5	101 ± 0.1	192 ± 0.5
7 Aug.	3.3 ± 0.1	4.9 ± 0.1	23 ± 0.1	31 ± 0.2	75 ± 0.3	154 ± 0.2
14 Aug.	1.5 ± 0.1	2.4 ± 0.2	22 ± 0.1	28 ± 0.2	33 ± 0.3	67 ± 0.2
Trend	Q†*	Q*	Q*	Q*	Q*	Q*

* Significant at $P = 0.05$.

† Q = quadratic.

delay (14 August vs. 1 August) resulted in a reduction of faba bean biomass of up to 62 and 55% in 2013 and 2014, respectively. Drier conditions in 2013, especially during the month of October when faba bean is actively growing, could in part explain the difference in total biomass production in the 2 yr of this experiment. We presumed that a higher *Rhizobium* population in the soil in the second year of the experiment could also have played a role in the production of more faba bean biomass in 2014. The presence of higher N concentrations in faba bean tissues in 2014 support this assumption (Table 2).

Nitrogen yield of a cover crop is a product of tissue N concentration and biomass accumulation, which indicates the potential amount of N that can be released into the soil during the decomposition process. Nitrogen accumulation of faba bean in 2013 and 2014 is presented in Table 2. As mentioned above, the N concentration in faba bean plants was significantly higher in 2014 compared with 2013. Although the *Rhizobium* population was not analyzed in this experiment, it is logical that the *Rhizobium* population would naturally be higher in the second year of the experiment conducted in the same location, compared with the first year of the study. The difference in the N concentration of faba bean in each year of the experiment could be at least partly attributed to the hypothesized higher bacterial population and resultant activity in 2014. The results indicate that faba bean sown on 1 Aug. 2014 accumulated as much as 192 kg ha^{-1} (Table 2), which is greater than earlier reports (Bremer et al., 1988; Unkovich and Pate, 2000; Cline and Silvernail, 2002), which reported that faba bean can fix up to 160 kg N ha^{-1}. Also, Duc et al. (1988) and Schwenke et al. (1998) reported that faba bean can fix up to 330 kg N ha^{-1}.

Additionally, in the dryer condition of 2013, faba bean fixed 50% less N than in 2014, averaged over the three planting dates. The results obtained in the current study, as well as in earlier reports (Oplinger et al., 1990; Baddeley et al., 2014), revealed that in general, faba bean and its associated *Rhizobium* are more efficient in fixing atmospheric N than vetch (Spargo et al., 2016; Mirsky et al., 2017) and many other grain legumes (Peoples et al., 2009).

The trends of N release for each of the two tillage systems are presented in Fig. 1. When the first decomposition sample was retrieved on 1 April for analysis, almost 30% of the N content of the faba bean residues in CT, and 20% in NT, had already been mineralized. The difference in the N release rate between the two tillage systems widened as the growing season progressed. Rapid decomposition of cover crop residues is not necessarily desirable, because the mineralized N is subject to various avenues of environmental loss if it is not captured by plants (Lupwayi et al., 2004; Tonitto et al., 2006; Cook et al., 2010). The results confirmed our hypothesis and also the earlier report by Drinkwater et al. (2000) that the use of a NT method would slow down decomposition of faba bean residues, providing a better timing between N mineralization and N uptake by sweet corn plants. In a CT system, almost 50% of N was released by the end of May, whereas in NT, release of 50% of N was delayed for approximately one month and occurred at the end of June. In New England, sweet corn traditionally is planted in early-mid May and commences its rapid growth stage in mid-June (4R Plant Nutrition, International Plant Nutrition Institute, 2015). Therefore, the delay in 50% N release from faba bean residues can significantly improve the synchrony between N release from faba bean residues and N uptake by sweet corn.

Sweet Corn Yield

Influence of Faba Bean Residues and Tillage Systems

Sweet corn marketable ear number and fresh ear yield, as well as percentage of unfilled ear tip, were significantly influenced by the amount of faba bean biomass accumulated at each planting date (Table 3). Averaged over 2 yr, sweet corn planted into residues of the earliest sown faba bean produced roughly 19% more marketable ear, 23% higher fresh ear weight, and 39% less unfilled ear tip compared with those grown in no faba bean plots (Table 3). The positive influence of faba bean residues on aforementioned traits dropped to 11, 7, and 6%, respectively, when planting of faba bean was delayed for only 2 wk. The difference in influence of faba bean residues on yield performance of sweet corn is mainly attributed to the total N contribution of their residues (Table 2).

As previously stated, more ecological benefits can generally be expected from higher cover crop biomass production. In addition to the higher accumulated N in early sown faba bean residues, other factors, such as type of tillage system, might have played a role in this study. Marketable ear yield of sweet corn were significantly higher in NT than in CT systems (Fig. 2a). Averaged over faba bean residue, sweet corn plants produced roughly 22% higher marketable ear and 31% less unfilled ear tip compared with a conventional system (Fig. 2a, b). This could be primarily due to better synchrony existed between faba bean decomposition with sweet corn growth in a no-till system (Fig. 1). The interaction between a tillage system and presence of faba bean residue was significant. For example, the ear yield difference between corn grown into faba bean residues was higher in no-till plots compared with a conventional tillage system (Fig. 4). Averaged over 2 yr, the maximum marketable ear (12.8 Mg ha^{-1}) was obtained from corn planted in no-till plots covered with faba bean residues (Fig. 4). Reports on the influence of tillage systems on sweet corn yield planted following various types of cover crops are contradictory and seem greatly influenced by the amount of residues produced at cover

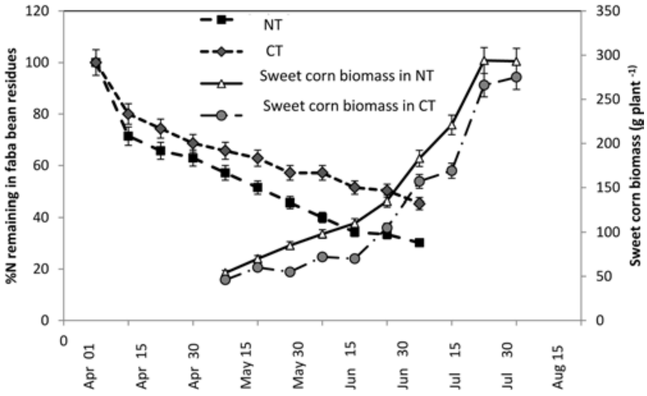

Fig. 1. Nitrogen release trend from decomposing faba bean residues in conventional tillage (CT) and no-till (NT) systems and sweet corn growth pattern. Means are averaged over two growing seasons.

crop termination time (Teasdale et al., 2008) and the C/N ratio of the cover crops (Cline and Silvernail, 2002; Kuo and Jellum, 2002). Cline and Silvernail (2002) concluded that NT sweet corn yielded similar to CT when planted after vetch, whereas sweet corn grown after rye or rye–vetch mixtures experienced a yield penalty. In addition to C/N, time and method of termination of cover crops may also interact with the influence of a tillage system. Winter legumes grown as green manure in spring and/or summer generally have a lower C/N, and they thus release substantial amounts of N in CT systems. In NT systems, the release of N is slower and therefore may not meet the N requirement of a high N demanding crop such as sweet corn.

Recently, Lowry and Brainard (2017) reported that the influence of the tillage system on organic sweet corn biomass is pronounced when soil moisture was non-limiting. Also, the lack or negative response of NT systems on integrated organic cover crop/sweet corn production might be related to a higher weed population that is usually higher in NT compared with CT systems.

Influence of Supplement Nitrogen Application

In both years, averaged over faba bean planting dates and tillage systems, the response of sweet corn marketable ear number and fresh ear yield to application of supplemental N was quadratic (Table 3) and reached its peak at approximately 80 kg N ha^{-1} (Fig. 3). Unfilled ear tip decreased linearly as N application rate increased (Table 3). As expected, the response of sweet corn to supplemental N was more pronounced when sweet corn was planted in plots without a prior faba bean cover crop (Fig. 3). In plots with no faba bean cover crop, a linear increase in sweet corn marketable ear yield was detected with increased supplement N fertilizer rate (Fig. 3). Although the faba bean cover crop was effective in fixing and conserving N, the faba bean residues did not provide sufficient N to the following sweet corn crop. As a result, when corn was planted into faba bean residues, an asymptotic response to increased N application rate with a peak at approximately 60 kg ha^{-1} was observed (Fig. 3). The impact of faba bean residues on sweet corn response to supplemental N was more noticeable in 2014 than 2015, presumably due to differences in the amount of percipiation (Table 1). The results obtained from this study do not confirm some of the earlier reports (Griffin et al., 2000; Cline and Silvernail, 2002) that indicated sweet corn planted after a legume cover crop usually does not respond to supplemental N. Based on results obtained in the current study, we concluded that averaged over 2 yr, the yield of sweet corn grown after faba bean was responsive to the first three increments of N up to 60 kg ha^{-1}, as opposed to the linear response in no faba bean plots. We found no significant interaction between faba bean date of planting and tillage system or between supplemental N application rate and tillage system.

Table 3. Sweet corn marketable ear number and fresh ear yield and unfilled tip percentage affected by faba bean (FB) residues planted at three dates of planting (DOP) and supplement N application rate to sweet corn.

	Ear no.		Ear wt.		Unfilled ear tip	
Treatments	2014	2015	2014	2015	2014	2015
	—— ha^{-1} ——		—— Mg ha^{-1} ——		—— % ——	
FB DOP						
1 Aug.	51,793	55,380	11.94	13.53	11.1	5.8
7 Aug.	49,800	52,591	10.34	12.73	16.4	7.2
14 Aug.	45,760	51,630	9.85	11.14	17.4	8.5
No FB	38,547	48,607	9.15	10.43	18.3	9.2
Trend	L†*	L*	Q*	L*	Q*	L*
Supp. N rate, kg ha^{-1}						
0	37,050	45,816	6.37	9.95	17.1	10.0
25	49,005	54,582	11.14	12.73	16.4	8.2
50	52,629	57,568	11.65	14.32	14.3	6.6
75	52,721	57,680	11.66	14.33	14.2	6.1
100	53,754	58,621	11.78	14.43	13.9	5.6
Trend	Q*	Q*	Q*	Q*	L*	L*

* Significance at $P = 0.05$; ns = not significant.

† L and Q = linear and quadratic, respectively.

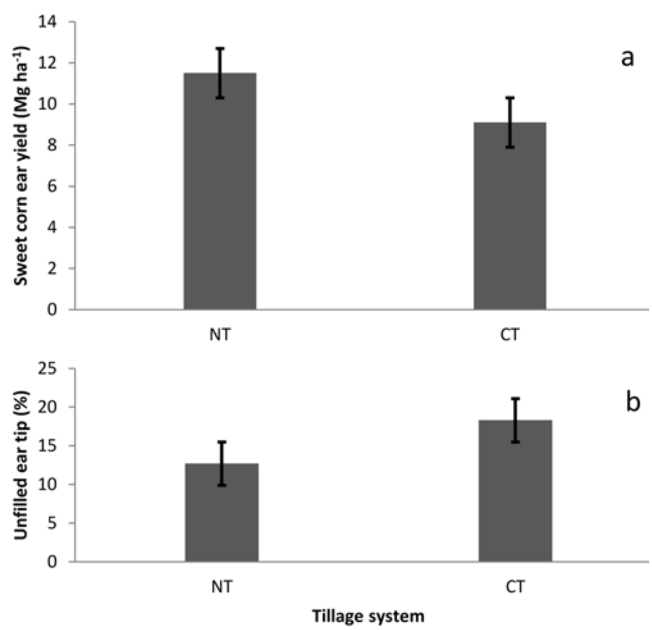

Fig. 2. Effect of tillage system on sweet corn ear yield (a) and unfilled ear tip percentage (b). Means are averaged over three faba bean dates of planting and two growing seasons.

Further investigation on faba bean as the major N source for succeeding vegetables under different sets of environmental conditions and management practices would be valuable for developing strategies to increase economic returns and to limit adverse environmental impacts of commercial fertilizers.

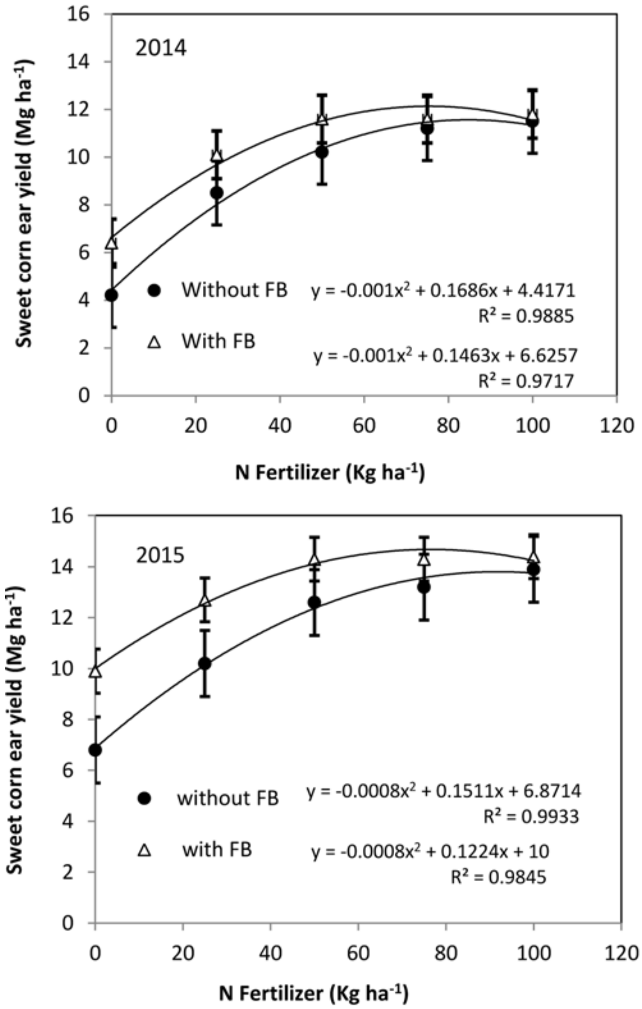

Fig. 3. Sweet corn ear yield influenced by presence or absence of faba bean residues and supplement N fertilizer rates in 2014 and 2015. Values are averaged over two tillage systems.

CONCLUSION

The results of this experiment provide a better understanding of the efficiency of N contribution of faba bean grown as a cover crop in rotation with sweet corn in the northeastern United States. Nitrogen yield of faba bean is a function of both its biomass production and its plant tissue N concentration. Therefore, earlier planting of faba bean dramatically influences the potential N that could be fixed and subsequently contributed to the following crop. In the current study, our measurements revealed that potential N was as much as 192 kg N ha^{-1} when faba bean was planted as early as 1 August and weather conditions were favorable (2014). The tillage system can significantly influence the trend of residue decomposition. No-till system delayed 50% N release from faba bean residues by approximately one month, which can significantly improve the synchrony between mineralization of faba bean residues and N uptake by sweet corn. Sweet corn planted into faba bean residues produced greater marketable ear number, higher fresh ear weight, and less unfilled ear tip compared with those grown in no faba bean plots. Since fall-grown faba bean is not considered to be a high-residue cover crop, spring-sown sweet corn can benefit from NT compared with CT system. Averaged over 2 yr and faba bean planting dates, sweet corn yielded 26% higher

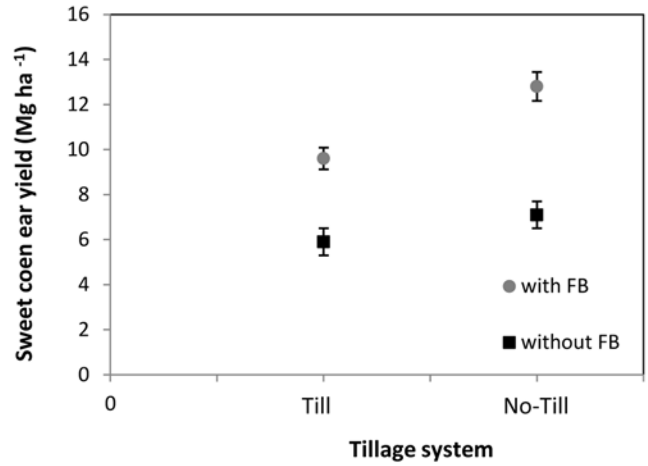

Fig. 4. Interactive effect of tillage system and faba bean residues on sweet corn ear yield. Values are averaged over 2014 and 2015.

and unfilled ear tip 30% lower in NT compared with CT, respectively. Although the faba bean cover crop was effective in fixing and conserving N, its residues did not provide sufficient N to the following sweet corn crop. On average, sweet corn responded positively to applications of supplemental N up to 60 kg ha^{-1}. Averaged over 2 yr, sweet corn following faba bean, plus approximately 50 kg N ha^{-1}, yielded similarly to those that received 100 kg N ha^{-1} without a prior faba bean cover crop.

ACKNOWLEDGMENTS

This material is based on work supported through grants awarded by Northeast SARE and Massachusetts Department of Agriculture. Authors thank Neal Woodard, Sarah Weis, and Kelly Kraemer for their field work assistance.

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