

The effects of different autumn-seeded cover crops on subsequent irrigated corn response to nitrogen fertilizer

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ABSTRACT

A common crop rotation in the west Iran is wheat-fallow-corn. The fallow period after wheat harvest (during fall and winter) can lead to soil erosion, nutrient losses (e.g. nitrate leaching) and offsite movement of pesticides. This period is an ideal time to establish a cover crop. In order to investigate the effects of different autumn-seeded cover crops on subsequent irrigated corn response to nitrogen fertilizer, field studies were carried out during the 2007-2008 growing season at the Agricultural Research Farm, Razi University, Kermanshah, Iran. The experiment was conducted in a split plot arrangement based on a randomized complete block design with three replications. The main plots consisted of four cover crops including alfalfa (*Medicago sativa* L.), berseem clover (*Trifolium alexandrinum* L.), common vetch (*Vicia sativa* L.) and winter rye (*Secale cereale* L.) and a control (no cover crop). The sub plots consisted of two fertilizer N rates (0 and 250 kg ha⁻¹). Cover crops were grown for nearly 5 months and then were incorporated into the soil as green manures. The results indicated that corn plant traits including seed yield, the number of seeds per ear and leaf chlorophyll content were significantly influenced by cover crops. Whereas, the cover crops had no significant effects on the number of ears per plant, 100-seed weight and harvest index of corn. Among the cover crop species, common vetch produced higher dry weight and showed the highest positive effects on the corn plant traits. Dry weight produced by this cover crop was 56.41, 120.16 and 124.19% higher than those of winter rye, berseem clover and alfalfa, respectively. Common vetch enhanced seed yield, the

number of seeds per ear and leaf chlorophyll content of corn by 46.30, 21.95 and 8.52%, respectively, compared to control. All of the corn traits under study, except the number of ears per plant and harvest index were significantly improved by nitrogen fertilizer. In general, this study revealed that the autumn-seeded cover crops, especially common vetch can be used to improve corn yield. However, the cover crops should be supplemented with nitrogen fertilizer to obtain optimal results.

Keywords: Corn; Cover Crop; Nitrogen Fertilizer

1. INTRODUCTION

A common crop rotation in the west Iran is wheat-fallow-corn. The fallow period after wheat harvest (during fall and winter) can lead to soil erosion, nutrient losses (e.g. nitrate leaching) and offsite movement of pesticides. In addition, weeds can germinate and grow without competition [1]. This period is an ideal time to establish a cover crop. Cover crops can be readily incorporated into crop rotations that include cereals [2]. A well-chosen cover crop can intercept raindrops and reduce water runoff, soil erosion and protect streams from pollution [1]. However, the protection that such vegetation provides against erosion is influenced mainly by the amount of biomass that covers the ground (differs with each spp) [3]. Cover crops have also been shown to increase the number of organisms which are natural enemies of some crop pests [1]. These crops offer habitat or resources for beneficial organisms [4,5]. For example, populations of ground-dwelling predators were greater in a corn and soybean rotation with alfalfa and kura clover cover crops than without a cover crop [6]. Studies focusing on legume cover crops establishment following cereals have reported considerable N contribution to a subsequent

corn crop [7,8].

Brophy *et al.* [9] suggested that when cover crops are turned over into the soil as green manures, they contribute nutrients to the main crop so that less chemical fertilizer required. However, the amount of the contribution depends on the biomass which varies over time and depends on rainfall and other factors. Lehman *et al.* [10] also noted that the legume cover crops have imported positive effects on the nutrient cycling in three ways: 1) recycling soil nutrients 2) enhancing soil nutrient availability for the main crop and 3) fixing the atmospheric N₂ that is important for the main crop. However, crop yield responses to additional fertilizer N continue to occur in some environments and certain management systems [11,12].

Nonlegume cover crops, primarily winter rye, are also used during the overwinter period to reduce wind erosion and potentially recover residual N from the soil or provide other benefits to subsequent crops [13]. Several studies [14-16] showed that significant amounts of N can be accumulated by nonlegume cover crops. Bundy and Andraski [13] reported that corn grain yields at below optimum N rates (0 and 112 kg ha⁻¹) were significantly higher where the rye cover crop was grown. However, legume cover crop species are often preferable to nonlegumes because they supply their own N. In general, biological N fixation (for legumes) and overall N accumulation during growth are primary factors governing the adequacy of a cover crop as an N source. Moreover, genetic differences (species and variety) may dictate that some legumes grow larger and accumulate more N than others. Environment (temperature, soil type and nutrient and water availability) and management (e.g., planting density and timing, mowing, and pest control) may further alter performance of individual cover crop species [17-19]. Because they do not derive direct sales profit, cover crop species are often chosen that require acceptably low levels of nutrient, irrigation, and pest control inputs and often fit into otherwise unplanted fallow periods. However, despite the positive effects often produced by winter annual cover crops in corn production, there is also a potential for reduction in corn yield [20]. Therefore, the success of these kinds of cropping system is largely determined by the selection of the most appropriate cover crop species and there is no consensus as to which cover crops import more positive effects on corn yield.

The present study was conducted to evaluate the effects of different cover crops (non-legume and legume species) planted during the fallow period (after wheat harvest) on subsequent irrigated corn response to nitrogen fertilizer in the west Iran.

2. MATERIALS AND METHODS

The study was carried out during the 2007-2008 growing season at the Agricultural Research Farm of Razi University, Kermanshah, west Iran. The soil type was a silty clay with a pH of 7.9–8.3 and 0.8% organic matter. The field was planted with wheat (*Triticum aestivum* L.) the previous growing season. The land was plowed and disked before crops planting. Fertilizers were applied according to the soil test recommendations. For all crops, irrigation was applied at germination and thereafter to prevent water stress. Weeds were controlled as needed during all of the growing season.

The experiment was conducted in a split plot arrangement based on a randomized complete block design with three replications. The main plots consisted of four cover crops and a control (no cover crop). The cover crop species evaluated were alfalfa (*Medicago sativa* L.), berseem clover (*Trifolium alexandrinum* L.), common vetch (*Vicia sativa* L.) and winter rye (*Secale cereale* L.). These cover crop species were selected according to environmental conditions and economic considerations of the region. Before corn planting, each main plot was split into two sub plots. The sub plots consisted of two fertilizer N rates (0 and 250 kg ha⁻¹) applied in the form of urea. Cover crops were seeded on 12 October 2007 by surface broadcasting at seeding rates of 50 kg ha⁻¹ alfalfa, 50 kg ha⁻¹ berseem clover, 250 kg ha⁻¹ common vetch and 220 kg ha⁻¹ winter rye. The seeding rate of each cover crop treatment was based on the recommended forage seeding rate for that crop in the region. Cover crops were grown for nearly 5 months and then were incorporated into the soil as green manures on 16 March 2008. Before incorporation cover crop dry weights were determined by harvesting them at ground level in three random 0.5 × 0.5 m quadrats in each sub plot. Then cover crop plants were dried at 80°C to the constant weights and weighed.

The corn cultivar used was 'KSC 704' (a grain corn cultivar that is commonly planted in the region). In order to protect against soil-borne diseases, prior to seeding, the corn seeds were treated with benomyl at 0.2% (w/w). Corn was planted in the sub plots on 2 May 2008. Each sub plot consisted of five corn rows of 5 m long with a row spacing of 75 cm and with 20 cm between plants in the same row. At tasselling stage leaf chlorophyll content of corn plants was determined on 10 randomly selected plants of each plot using a chlorophyll meter (SPAD-502; Minolta, Osaka, Japan).

At maturity, the corn plants located 2 m from the three center rows of each sub plot were harvested by hand, allowed to dry at 80°C to a constant weight, then threshed and seed yield (g m⁻²) was obtained and reported based

on a moisture content of 15.5%. Before final harvesting corn yield components including the number of ears per plant and the number of seeds per ear were determined on five randomly selected plants in the center rows of each sub plot. Additionally, 100-seed weight was measured according to the recommendation of the International Seed Testing Association (ISTA) [21]. Harvest index was calculated as the ratio of seed weight to total shoot weight [22]. The data analyses were carried out using SAS software [23].

3. RESULTS AND DISCUSSION

According to analysis of variance (data not shown) there was a significant difference (at the 0.01 level of probability) between the dry weights produced by different cover crop species under study. Moreover, corn plant traits including seed yield, the number of seeds per ear, 100-seed weight and leaf chlorophyll content were significantly influenced by nitrogen fertilizer treatment. Whereas, the effect of cover crop treatment was statistically significant for seed yield, the number of seeds per ear and leaf chlorophyll content. Both nitrogen fertilizer and cover crop treatments had no significant effects on the number of ears per plant and harvest index of corn. Moreover, the two way interaction (cover crop treatment \times nitrogen fertilizer level) was not significant for all of the traits under study.

Among the cover crop species, common vetch produced higher dry weight at the time of the incorporation into the soil (**Table 1**). Dry weight produced by common vetch was 56.41, 120.16 and 124.19% higher than those of winter rye, berseem clover and alfalfa, respectively (**Table 1**). Alfalfa produced the lowest dry weight, although there was no significant difference between this cover crop and berseem clover for the dry weight produced (**Table 1**). Although, winter rye produced higher

dry weight than those of berseem clover and alfalfa, but the corn plant traits were not significantly improved by this cover crop (**Table 1**). According to Ranells and Waggar [24] non leguminous cover crops typically have low N contents and high C/N ratios, showing litter or no beneficial effects on the succeeding crop yield. As determined visually, common vetch also produced a dense canopy on the ground surface throughout the growing season. This can be attributed to the better establishment and growth of this cover crop under environmental condition of the region as compared with other cover crops under study. In temperate environments winter-hardy legumes such as vetch are capable of accumulating large amounts of biomass and N and delivering substantial N benefit to subsequent spring-planted crops [25].

All of the corn plant traits under study except the number of ears per plant and harvest index were significantly improved by nitrogen fertilizer applied at 250 kg ha⁻¹ (**Table 2**). Overall, this treatment increased seed yield, the number of seeds per ear, 100-seed weight and leaf chlorophyll content by 61.24, 96.83, 12.05 and 19.23%, respectively, when compared with the treatment in which no nitrogen fertilizer was applied (**Table 2**). According to Thonnissen *et al.* [26] with respect to season and location, green manure N should be supplemented with N fertilizer to ensure optimal yields.

Among the cover crop species, common vetch showed the highest positive effects on the corn plant traits. This cover crop enhanced seed yield, the number of seeds per ear and leaf chlorophyll content by 46.30, 21.95 and 8.52%, respectively, compared to control (no cover crop) (**Table 1**). However, the number of ears per plant, 100-seed weight and harvest index of corn were not significantly affected by common vetch or other cover crops (**Table 1**). Moreover, there were no significant differences between other cover crops and control for

Table 1. Means comparison of the traits under different cover crop treatments.

Cover crop treatment	Corn						Cover crop dry weight (g m ⁻²)
	Seed yield (g m ⁻²)	Seeds per ear (N)	100-seed weight (g)	Ears per plant (N)	Leaf chlorophyll content (SPAD value)	Harvest index	
Common vetch	924.14 a	548.61 a	24.92 a	1.02 a	53.51 a	0.39 a	306.29 a
Alfalfa	734.49 b	462.29 b	24.03 a	1.00 a	47.20 bc	0.37 a	136.62 c
Berseem clover	737.26 b	448.76 b	25.18 a	1.01 a	47.07 bc	0.37 a	139.12 c
Rye	702.17 b	449.89 b	26.00 a	0.94 a	44.28 c	0.37 a	195.82 b
Control (no cover crop)	631.68 b	449.85 b	23.11 a	0.94 a	49.31 b	0.37 a	000.00 d
LSD (0.05)	174.79	53.88	5.19	0.10	3.69	0.03	42.54

The same letters at each column indicate an insignificant difference at the 0.05 level of probability. LSD, least significant difference; SPAD, refers to the chlorophyll meter.

Table 2. Means comparison of corn plant traits under different nitrogen fertilizer levels.

Nitrogen fertilizer level (kg ha ⁻¹)	Corn					
	Seed yield (g m ⁻²)	Seeds per ear (N)	100-seed weight (g)	Ears per plant (N)	Leaf chlorophyll content (SPAD value)	Harvest index
250	920.80 a	623.16 a	26.04 a	0.99 a	52.51 a	0.38 a
0	571.08 b	316.60 b	23.24 b	0.97 a	44.04 b	0.37 a
LSD (0.05)	87.42	63.29	2.08	0.04	6.26	0.02

Dissimilar letters at each column indicate a significant difference at the 0.05 level of probability. LSD, least significant difference; SPAD, refers to the chlorophyll meter.

seed yield and the number of seeds per ear of corn. Corn seed yields were improved by 16.71, 16.28 and 11.16% following berseem clover, alfalfa and winter rye, respectively, when compared with control, but these improvements were not statistically significant (**Table 1**). Leaf chlorophyll content of corn was significantly lower in winter rye treatment than control, so that, this cover crop caused the reduction of 10.20% in leaf chlorophyll content of corn plant as compared with control (**Table 1**). This can be attributed to the higher C/N ratio in plant tissues of non-legume cover crops such as winter rye [27] that consequently lead to the slower decomposition and N release of their plant tissues [28] and strong N immobilization after these crops are added as green manures into the soil [29]. This can result in reduced N availability to corn.

The enhancement of leaf chlorophyll content by common vetch can be due to the improved soil nitrogen condition by incorporated common vetch plants. This can be led to the increased leaf nitrogen content [30]. Nitrogen is a substantial element of the chlorophyll structure, so that, a positive correlation between leaf nitrogen and chlorophyll content is well documented for a number of plant species [31-34]. Moreover, the positive significant correlations between photosynthesis and leaf nitrogen content have been proved for a large number of species [35-40]. The improvement of photosynthesis due to increased leaf chlorophyll content ultimately can result in the enhancement of corn growth and yield.

Moreover, higher corn seed yield in the plots in which common vetch was incorporated into the soil can be as a result of the higher dry weight produced by this cover crop that consequently led to the improvement of soil condition and nutrient supplement to corn plants. This was supported by a significant and positive correlation between corn seed yield and cover crop dry weight ($r = 0.67$; $P < 0.01$). According to Brophy *et al.* [9] when cover crops are turned over into the soil as green manures they contribute nutrients to the main crop. The amount of the contribution depends on the biomass which varies over time and depends on cover crop spe-

cies and other factors.

Nitrogen fertilizer applied at the level of 250 kg ha⁻¹ increased corn seed yield by 129.03, 71.59, 59.08, 47.25 and 33.62% following control (no cover crop), winter rye, alfalfa, berseem clover and common vetch treatments, respectively, when compared with the treatment in which no nitrogen fertilizer was applied (**Figure 1**). In other words, nitrogen application improved corn seed yield following all of the cover crop treatments. However, the highest improvement occurred at the control plots (**Figure 1**). Moreover, there were lower corn seed yield responses to nitrogen fertilizer following legume cover crops than rye, so that, the highest and the lowest enhancements of corn seed yields due to the applied nitrogen fertilizer were obtained following winter rye and common vetch cover crops, respectively (**Figure 1**).

Overall, improvements of the corn plant traits in response to the applied nitrogen fertilizer indicated that the nitrogen released from the incorporated cover crops was not sufficient to support the potential corn growth and yield. Griffin *et al.* [41] also reported that cover crops can supply all or most of the N required by a subsequent crop if cover crop biomass is of sufficient quantity and N mineralization is approximately synchronous with sub

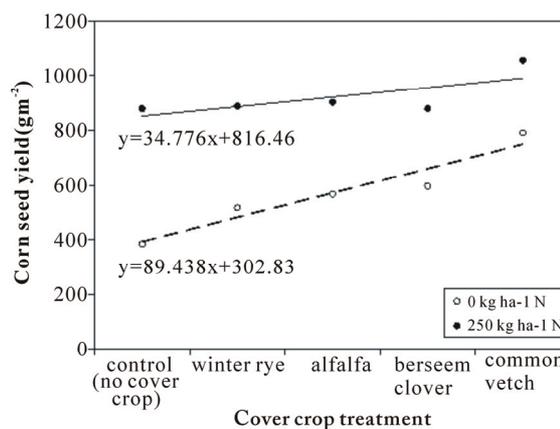


Figure 1. The effect of different cover crop treatments on corn seed yield under two nitrogen fertilizer levels (0 and 250 kg ha⁻¹).

sequent crop demand. However, studies evaluating the effect of ^{15}N from legume residues decomposing under field conditions lead to the conclusions that < 30% of legume N was recovered by a subsequent nonlegume crop and large amounts of legume N were retained in soil, mostly in organic forms [42-44]. Kuo and Jellum [45] also found that corn yields were affected by N fertilizer applied irrespective of cover crop species.

In general, this study revealed that the autumn-seeded cover crops, especially common vetch can be used to improve corn yield. However, the cover crops should be supplemented with nitrogen fertilizer to obtain optimal results.

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