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# WINTER COVER EVALUATION OF ECOPHYSIO

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Integrating winter cover crops (WCC) in a cropping system provides benefits that can result in enhanced crop yield. Although it is important to recognize that WCC can increase corn yield and provide environmental benefits, management practices need to be adapted to specific regions and cropping systems to increase the positive effects of WCC on corn yield and the environment. Correspondingly, in cropping systems where use of WCC may result in lower corn yields, possible negative effects need to be decreased.

In Illinois, a statewide average of 4,300,000 ha (10,600,000 acres) of corn were planted annually between 1993 and 2002, and each year at least 175 kg ha<sup>-1</sup> (156 lb/A) of nitrogen fertilizer was used in 94 percent of the planted area.

Bollero and Bullock showed that corn yield increase due to hairy vetch did not compensate economically for the cost of the seed, planting operations and herbicide application. Further research showed that hairy vetch and/or rye alone do not provide sufficient nitrogen to optimize corn grain yields. However, the previous studies indicated that management tools such as fertilization and the WCC kill date need to be adapted to a specific region and cropping system.

Ruffo and Bollero concluded that in this region killing cereal rye one week before planting corn was not optimal for adequate synchronization between nitrogen release from the residue and nitrogen demand for corn. Crandall et al. evaluated kill date and fertilization strategies with the goal of improving the synchronization of nitrogen demand for corn and supply from the cropping system while minimizing

nitrogen losses. They concluded that applying nitrogen fertilizer at planting and killing cereal rye two weeks before planting corn produced yields comparable to corn following no cover.

Most importantly, Crandall et al. showed that through adequate management practices, crop productivity can be maintained and negative effects to the environment can be reduced, thus suggesting that these are not conflicting goals.

Evaluating ecophysiological characteristics of corn under WCCs can lead to improved management decisions that maximize positive effects and minimize negative effects associated with the use of WCCs. In the future, this may promote a greater acceptance of WCCs among Illinois farmers who may need to comply with state laws to reduce the use of fertilizer, address soil erosion and/or reduce the use of other agrochemicals. The objective of this study was to examine corn development, growth and yield through the evaluation of ecophysiological characteristics (i.e., morphological characteristics, development, light interception (LI), carbon exchange, chlorophyll readings, and yield components) of corn following WCC and a no-cover control.

## MATERIALS AND METHODS

**Field Site and Method.** This two-year field experiment was conducted at Urbana, Ill., during 2002 and 2003. The soil is a Drummer silty clay loam. The experiment was conducted using no-till practices in plots that were previously in corn-soybean rotation for at least seven years. Winter cover crops were drilled on soybean stubble

in adjacent fields each year. Corn was planted using 76-cm (30-inch) row spacing on May 1, 2002, and April 29, 2003.

### Morphological Characteristics.

In 2003, selected morphological characteristics of corn were recorded: height (from the ground to the base of the uppermost fully expanded leaf), number of fully expanded leaves and area of the uppermost fully expanded leaf. The area of the uppermost fully expanded leaf was calculated as maximum leaf length  $\times$  maximum leaf width  $\times$  0.75.

Two plants per plot were randomly selected in each subplot for these measurements.

### Chlorophyll Meter Readings.

Corn nitrogen status was evaluated using a chlorophyll meter. Readings were taken on the uppermost fully expanded leaf with a visible collar during vegetative growth and from the ear leaf during reproductive growth. A subsample of 10 corn plants was measured around R1 in each subplot.

**Light Interception.** The photosynthetic active radiation (PAR,  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) intercepted by the crop was recorded using a 0.8-meter-long Sunfleck PAR Ceptometer.

Measurements were taken on cloudless days between 1100 and 1400 hours when the external sensor read at least 1400  $\mu\text{mol m}^{-2} \text{s}^{-1}$  photosynthetic photon flux density (PPFD). Light interception (LI) is reported as a percentage of the PAR intercepted by the corn crop over the PAR recorded by an external sensor.

**Leaf Carbon Dioxide Exchange Rate.** Leaf carbon dioxide exchange rates (CER), ( $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ ) were measured using a portable, open-flow

# CROPS IN ILLINOIS

## LOGICAL CHARACTERISTICS OF CORN

gas exchange system LI-6400. An area of 6 cm<sup>2</sup> (1 square inch) that did not include the midrib was chosen on a sun-lit fully expanded leaf.

### **Yield and Yield Components**

**Methods.** The two and four central rows of each plot in 2002 and 2003, respectively, were mechanically harvested. Yield was corrected for moisture at 155 g kg<sup>-1</sup> (15.5%). Three corn plants were collected before harvest (avoiding the center rows) to determine yield components. Plants were dried to a constant weight at 65°C (150°F) and stems, leaves and kernels were weighed. Kernel number and weight were also determined for each sample.

## **RESULTS AND DISCUSSION**

### **Winter Cover Crop**

**Biomass.** Biomass production of WCCs differed substantially between years. A possible reason for this difference was planting dates. Because of weather conditions in 2001, WCCs were planted a month later than in 2002. These differences in biomass production show the widely reported importance of early fall planting for successful WCC establishment and biomass production. This is especially true for hairy vetch, which is more susceptible to winterkill than rye. Although hairy vetch winterkill was not specifically measured in this study, the low biomass production indicates that plants were lost. However, the biomass for the other WCCs was also low, suggesting that conditions were not ideal for WCC growth.

Hairy vetch biomass showed a similar range compared with other studies in Illinois. In this study, the average carbon/nitrogen (C/N) ratio

was 12 and 14 for 2002 and 2004, respectively. These values are lower than the average 17 reported by Ruffo and Bollero for Illinois. The C/N ratio of the rye in monoculture and biculture is lower than the values reported in Ruffo and Bollero, probably as a result of the different management.

Killing rye two weeks earlier is a compromise between the biomass produced and the lower C/N ratio. A lower C/N in the rye in monoculture reduced the negative effects due to immobilization. Probably, if rye were killed two weeks later, the C/N ratio would be much higher and closer to 25. The low C/N ratios reported here are similar to those in Ruffo et al. for the higher nitrogen fertilizer rate (NFR).

### **Corn Morphological**

**Characteristics.** The results of the analysis of corn morphological characteristics demonstrate that rye in monoculture had detrimental effects on corn development. The differences found in leaf number, height and leaf area indicate that corn following rye resulted in a smaller plant and consequently a reduced canopy, which probably led to lower efficiency in intercepting solar radiation. However, most of the detrimental effects were observed at 0 kg N ha<sup>-1</sup> (0 lbs/A) and these negative effects were partially or completely overcome by adding 90 kg N ha<sup>-1</sup> (80 lbs/A). There were no negative effects at higher NFR. This suggests that rye in monoculture not only did not effectively supply nitrogen to corn but rather caused immobilization of nitrogen and consequently nitrogen deficiency.

We hypothesize that, in this study, allelopathic effects were not the main



reason why rye had detrimental effects on corn development, because rye in monoculture was killed two weeks and rye in biculture one week before planting corn, and negative effects were clearer for rye in the monoculture. We would expect to encounter larger negative effects due to allelopathy where more rye biomass was present and when there was less time for compounds to leach. It is possible that below-ground biomass, which was not measured in this study, was responsible for the negative effects of rye on corn growth.

The effect of hairy vetch-rye biculture on corn development was intermediate to the effects of rye and



hairy vetch in monoculture or no cover. It is likely that the detrimental effects of hairy vetch-rye biculture on corn development can be attributed to the negative influence of rye as discussed above. However, the different management (i.e., later kill date) for the hairy vetch-rye biculture provided a greater dry biomass for both components of the biculture.

The contribution of hairy vetch to the biculture probably resulted in a greater nitrogen supply and a more balanced C/N ratio of the combined residue, and consequently a lower potential for nitrogen immobilization. Ideally, a hairy vetch-rye biculture can provide corn with benefits associated with both components, but in this study, corn development following hairy vetch-rye was not optimal compared with the response to no cover or hairy vetch in monoculture.

In Illinois, management of hairy vetch-rye biculture will require a minimum of 80 lbs/A to minimize the negative effects that are likely associated with rye. However, as shown in other states, the inclusion of rye in the biculture can be desirable because rye is more effective than hairy vetch in taking up residual nitrogen, and thus better reduces the potential for nitrogen loss from the cropping system.

**Corn Biomass.** Dry biomass of corn was affected by the preceding WCC for the combined analysis of years. Small differences in corn dry biomass early in the season, as shown for the morphological characteristics, were more pronounced at later stages of corn development. Corn following hairy vetch achieved a larger dry biomass than corn following other WCCs or no cover, but these differences were statistically significant only at harvest. The difference between corn following hairy vetch and corn following no cover at harvest cannot easily be explained by any of

the morphological variables analyzed. However, these variables focused on the early development of corn, and the observed differences might be a result of ecophysiological changes that occurred later in corn development.

#### **Carbon Dioxide Exchange Rate.**

The results of corn development and LI raise the question of how corn growth rate responded to WCCs. As for LI, statistical differences and differences in magnitude in CER were mainly found for corn that received no nitrogen fertilizer. At 0 nitrogen, corn following hairy vetch maintained CER comparable with higher NFR, while corn following rye had significantly reduced CER at no nitrogen. Corn following no cover and hairy vetch-rye biculture achieved intermediate CER.

These results reflect the growth rate of corn in the period before silking, which has been recognized as a critical period for kernel set, which is in turn closely associated with corn grain yield. The higher values of LI, combined with higher CERs, provided corn following hairy vetch an advantage over corn following any other WCC or no cover. Thus, although hairy vetch increased soil nitrogen availability to corn, it was not enough to provide the entire nitrogen needed for achieving high levels of LI.

**Corn Yield and Yield Components.** The predicted equations for corn grain yield for years combined as anticipated by the analysis of ecophysiological characteristics show that the largest differences were found at lower NFR. Although nonsignificant, the magnitude of the difference in corn grain yield following hairy vetch and no cover was 1.1 Mg ha<sup>-1</sup> (0.5 tons/A). Moreover, there were no significant differences between the intercept and the linear parameter of the regression equations for corn

following hairy vetch and no cover. Even though differences in corn yield for corn following hairy vetch at low NFR could be a result of higher LI and CER, it is not entirely clear what mechanisms are responsible for the difference observed between corn following hairy vetch and no cover at higher NFR.

Clark et al. found that hairy vetch residue was more effective in conserving soil moisture than no cover. Therefore, it is possible that in this study some of the beneficial effects attributed to hairy vetch are associated with improved soil moisture conservation. There were differences in corn grain yield between years. It is clear that two years do not provide a reliable estimate for this variance component, and that much of the variability in this study is due to factors that differed between years. Probably the two factors that varied the most were the precipitation in July and the dry biomass production by WCCs. More years of experimentation are needed to estimate the effects of highly variable annual weather patterns. In addition, a better approach to this issue is combining the results of studies which considered similar treatments using appropriate statistical methods.

Kernel number and weight increased with nitrogen fertilizer. As with previous variables, kernel number and weight only differed among WCCs when no nitrogen fertilizer was applied and as NFRs increased differences among WCCs were nonsignificant. Also, corn following hairy vetch had the highest mean for kernel number and weight, and corn following rye had the lowest.

In summary, the analysis of ecophysiological characteristics of corn following WCCs and no cover revealed that corn following hairy vetch was superior to all other treatments when no nitrogen fertilizer

was applied. The fact that most observed differences disappeared with nitrogen fertilizer suggests that most of the beneficial effects of hairy vetch are due to an improved soil nitrogen availability. However, in the regression analysis for grain yield, although the parameters were not statistically different, corn following hairy vetch yielded more than following no cover, suggesting that there might be beneficial effects associated with hairy vetch that are not solely due to nitrogen supply.

On the other hand, rye and hairy vetch-rye biculture had detrimental effects on corn, and this was almost always true when no nitrogen fertilizer was applied. No nitrogen fertilizer is an unrealistic scenario for

most farmers, and there were very few cases in which the negative effects were not overcome by application of 80 lbs/A N, which is below the average NFR used by Illinois farmers.

It is encouraging that the management practices used in this study did not cause negative effects on corn development and yield as long as at least 80 lbs/A N were applied. Thus, incorporating WCCs in a corn-soybean rotation in Illinois could provide environmental services without affecting corn yield potential. Furthermore, if hairy vetch is incorporated, the yield potential of corn might even increase above what would be expected under the prevalent cropping system in Illinois in which WCCs are not used. **AG**

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# Winter cover crops in Illinois: Evaluation of ecophysiological characteristics of corn September Self-Study Examination

**1. Winter cover crops have been recognized as an effective strategy for**

- a. decreasing crop input costs.
- b. maintaining nitrogen in the cropping system.
- c. equalizing variations in soil pH.
- d. releasing soil organic carbon.

**2. Bollero and Bullock concluded in an earlier study that**

- a. corn yield increases from using a vetch WCC did not pay for the cost of seed and associated field operations.
- b. hairy vetch and rye, if planted early, can provide sufficient N for optimum corn grain yields.
- c. corn planting rates need to be increased to compensate for poor planting conditions.
- d. mid-summer seedings are superior for the establishment of either vetch or rye.

**3. A feature of corn production in Illinois includes**

- a. about 12 million hectares planted annually.
- b. winter cover crops planted on most acres.
- c. at least 156 lb/A of nitrogen used on the majority of corn acres.
- d. dark prairie soils where nitrogen leaching is of little concern.

**4. Parameters measured in this study included**

- a. soil nitrate content.
- b. crop oxygen evolution.
- c. kernel number counts.
- d. crop root mass measurements.

**5. A characteristic of the study methods was**

- a. multiple locations across Southern Illinois.
- b. a variety of crops and crop rotations.
- c. conventional tillage.
- d. check plots that had no cover crops planted.

**6. A possible reason for the differences in biomass production of the winter cover crops between years was the**

- a. planting dates of cover crops.
- b. planting dates of the corn crop.
- c. differences in seed sources.
- d. herbicide differences in previous crops.

**7. As compared to rye, a characteristic of hairy vetch is that it**

- a. can provide more nitrogen to following crops.
- b. is more winter hardy.
- c. can be planted and managed less expensively.
- d. competes more vigorously with corn.

**8. A reason for the differences in corn morphology among different cover crop treatments was**

- a. allelopathic effects between the rye and corn.
- b. nitrogen tie-up.
- c. early-season shading and competition of cover crops.
- d. crop leaf diseases from cover crops serving as hosts.

**9. With no nitrogen fertilizer, the performance of corn was best when following**

- a. rye cover crops.
- b. no cover.
- c. hairy vetch.
- d. a hairy vetch/rye combination.

**10. For farmers using at least 80 lbs/A N, incorporating a WCC into their cropping system should**

- a. not cause negative effects on corn development or yield.
- b. increase yields.
- c. decrease expenses.
- d. eliminate environmental concerns regarding nitrogen.

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