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# The effect of Austrian winter-pea cover crop and cow-pea companion crop on corn yield

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## ABSTRACT

Leguminous cover crops have the potential to combat the rising input cost of commercial nitrogen (N) fertilizers. This experiment examines benefits of implementing a leguminous cover and/or companion crop into a corn production system. Legumes biologically fix nitrogen from the atmosphere, adding to the nitrogen content of the soil. In this experiment Austrian winter peas (*Pisum arvense*) (AWP) were used as the leguminous cover crop and cowpeas (*Vigna unguiculata*) were used as the companion crop. A two year experiment was carried out in which winter peas were planted on half the field in the fall and allowed to grow until late April to early May. The pea biomass was recorded, then the peas were plowed into the soil allowed to incorporate and begin decomposition, followed by corn planting. Different rates of commercial nitrogen were applied and varying seeding rates of companion-crop peas were also evaluated. Nitrogen was applied at 0, 112, and 224 kg $ha^{-1}$. Companion-crop peas were planted at 0, 4, and 8 plants $m^{-1}$. The corn was harvested, and yield as influenced by the various treatments, was evaluated. In both years, cover-crop peas provided all or a significant amount of corn N needs. This has useful implications for producer profitability and the environment since commercial N requires fossil fuels during its production.

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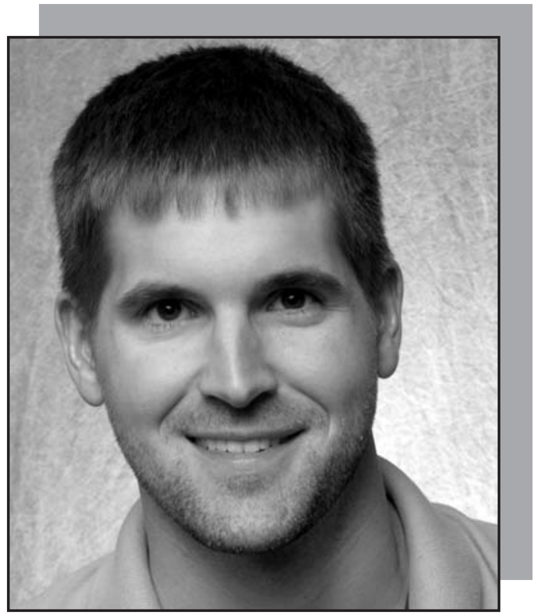
## INTRODUCTION

Cost of nitrogen (N) fertilizers has increased greatly in recent years. This is due to ever increasing cost of fossil fuels needed to produce commercial nitrogen fertilizers. To combat increasing economical and environmental costs of production, producers need a highly productive and sustainable alternative. It is becoming necessary for producers to maintain or increase productivity, and increase sustainability. For farming systems to adapt to do this long term, it will be necessary to replenish reserves of nutrients that are removed or lost from the soil (Peoples et al., 1995(a).) One possible way to achieve this is through use of cover cropping. A cover crop is the planting of grass or legumes on a field between production seasons. Such plantings reduce erosion, build soil, prevent leaching, and in the case of legumes, fix nitrogen for subsequent crops (Sullivan et al., 2003.) Management practices consisting of combinations of conservation tillage, mixtures of legume and non-legume cover crops, and reduced rates of N fertilizers have potential for sustaining crop yields, increasing soil carbon (C) and N storage, and reducing soil N leaching, thereby helping improve soil and water qualities (Sainj et al., 2003.) Winter cover crops may also increase soil organic matter while sequestering N and preventing leaching into the groundwater. This is important for the low-organic matter alluvial soils of the Mississippi River Delta. Intensive cropping of this area for many years has caused depletion of organic matter and brought about an urgent the need for its conservation (Mascagni et al., 1997.)

Use of a leguminous cover crop contributes biologically fixed nitrogen from the atmosphere, with potential for reducing the N fertilizer requirement (Mascagni et al., 1998.) Leguminous companion crops, defined as legumes planted along with the target crop, can also be implemented to reduce the N fertilizer requirement (Davis et al., 1991.) Atmospheric nitrogen is fixed symbiotically by associations between *Rhizobium* sp bacteria and legumes. This relationship represents a renewable source of N for agriculture. Contributions of legume $N_2$ fixation to the N-economy of any ecosystem are mediated by legume reliance upon $N_2$ fixation for growth, the total amount of legume-N accumulated, and legume biomass (Peoples et al., 1995(b).)

Some previous research shows legume cover crops can supply all or most of the N required by a

## MEET THE STUDENT-AUTHOR



*Matthew Marsh*

I have been involved in agriculture my entire life. My family has operated a farm near McCrory, Ark. for generations. This deep background has inspired my interest in agriculture at the University of Arkansas. After graduating from McCrory High School, I came to the University of Arkansas on an Arkansas Academic Challenge Scholarship. Throughout my career at the University I have been involved in many different organizations and events. I am a member of Kappa Sigma fraternity where I participated in many events with Greek life. I represented the Dale Bumpers College of Agricultural, Food and Life Sciences as a senator in Associated Student Government. I have also served as a peer mentor for incoming students of the Dale Bumpers College of Agricultural, Food and Life Sciences. To further my education outside the classroom, I interned with Monsanto Company throughout the summers of 2006 and 2007. This was an incredible experience that sparked my interest in research. I am graduating in May 2008 and plan on continuing my education here at the University of Arkansas with a master's degree in crop science.

target crop if legume biomass is of sufficient quantity and N mineralization is approximately synchronous with crop demand. In one such experiment, sweet corn following rye exhibited a linear response to N fertilizer (up to 156 kg N ha), but generally exhibited no response to added N fertilizer following legumes, alfalfa, or hairy vetch plus rye. In this experiment it was concluded that the legume cover crops grown were able to replace all or nearly all of the N fertilizer required by a subsequent sweet corn crop. These cover crops were found to be a viable alternative source of N, greatly reducing or eliminating the need for N fertilizer (Griffin et al., 2002)

In order to gain a better understanding rate of existing or emerging biological nitrogen fixation technologies, it has been proposed (Bantilan et al., 1995) that future research and development efforts focus on research adaptation and practical use. Giller et al. (1995) also stated that strategies enhancement and exploitation of biological nitrogen fixation be assessed with attention to the timescales for realization of benefits biological nitrogen fixation may have in agriculture. The experiment reported in this paper contributes to that objective. Immediate enhancements in inputs from $N_2$-fixation are possible by simple implementation of existing technical knowledge, such as cover cropping. Legume selection must be considered within the context of the farming system and geographical region in which specific legume species are grown. Proper integration of legumes requires a good understanding of the role of the legume within the system and a better understanding of the relative contributions of N sources and the fates of fixed N (Giller et al., 1995) We believe the experiment presented in these pages brings greater understanding of what leguminous cover crops can contribute to nitrogen requirements and replacement in corn. Our objectives in this study were to: 1) determine if all or a portion of seasonal N crop needs of corn could be met with cover and/or companion crops, and, 2) establish whether corn grown with cover crops can influence and perhaps improve the soil nutrient profile.

## MATERIALS AND METHODS

The field experiments were conducted over the time period of October 2005 until October 2007 at the University of Arkansas Agricultural Experiment Station, Fayetteville, on a silt loam soil. The experimental design was a basic split plot. The whole-plot portion was a randomized complete block (RCB) with one factor; AWP with two levels: AWP and no AWP. The split plot portion was a RBC with 4 replications and 2 treatment combinations which were nested within each experiment unit of the whole plot. For analysis purposes it was assumed that blocks and replications were random effects and winter peas, cowpeas and nitrogen were fixed effects.

Treatments were arranged as follows: winter cover crop (AWP, no AWP); intercrop cowpeas (0, 6, and 13 plants $m^{-1}$); and nitrogen fertilizer rates (0, 112, and 224 kg $ha^{-1}$). The plots were four rows (100 cm) wide and 3 meters long.

In October 2005 and 2006 the field was cultivated and half was planted in Austrian winter peas (14 kg/ha). In mid-May 2006 and 2007, respectively, the peas were mowed and disked into the soil when dry. The peas had begun flowering when mowing occurred. The field was bedded in 1-m rows. The field was cultivated and planted on June 1, 2006 and June 10, 2007 with Pioneer 31G96 at 62,000 plants per $ha^{-1}$. The cowpeas were planted along with corn at previously mentioned seeding rates. Nitrogen treatments were applied to plots as split applications by hand-scattering N, with precise amounts applied to each plot. The plots receiving 112 kg of N received a single application approximately 10 d after planting. Plots receiving 224 kg $ha^{-1}$ received 112 kg $ha^{-1}$ 10 d after planting, with the second 112 kg $ha^{-1}$ coming 30 d after planting.

Pea dry-matter yield was taken just before the AWP were mowed. Five one meter square areas of the AWP were harvested dried, and weighed. Weights were averaged and multiplied by the field area to determine the total dry-matter production. A portion of the dry matter was also analyzed for percent nitrogen content. Nitrogen percentage was multiplied by total dry-matter production to determine total nitrogen production by the pea aboveground dry matter.

Volumetric soil water content was measured in the 0- to 6-cm depth throughout the AWP cover-crop area and the non-cover-crop area just prior to pea harvesting. This was accomplished by using a Theta Probe (model TH20, Dynamax, Houston, Texas, USA), which records dielectric voltage readings and converts them to volumetric water contents using a soils-specific calibration equation.

Pesticide applications in 2006 were Duel Magnum, a selective herbicide labeled for most annual grasses and small-seeded broadleaf weeds formulated with *S-metolachlor* as the active ingredient, and Asana, an insecticide formulated with *esfenvalerate* as the active ingredient, to control a wide range of insects. The Duel Magnum application was made on June 9, 2006, one day prior to planting; it was applied at 1.56 liters $ha^{-1}$. Two Asana applications were made; the first being July 6 at .59 liters $ha^{-1}$ and the second on July 20 at .73 liters $ha^{-1}$. Weeds were also controlled with single-row cultivation on July 6, 2006. In 2007 Duel Magnum was applied June 1, 2007 at 1.56 liters $ha^{-1}$ prior to planting. Single-row cultivation was also used to control weeds in 2007. In 2007 no Asana application was made.

Irrigation was managed through row saturation from furrow irrigation, at the discretion of the farm manager. The water was applied via 15-cm aluminum pipe until furrows were saturated. Irrigation occurrences are shown in Table 1. In 2006 the field was irrigated 6 times and 4 times in 2007.

Entire corn ears were hand-harvested on October 12-13, 2006 and October 15-17, 2007. A 1.5-M portion of the middle two rows was harvested. The ears were bagged and dried to below 13% moisture. After drying, corn was shelled by hand using an electric sheller. Grain was then weighed and adjusted to 13% moisture. The data were analyzed by analysis of variance through (ANOVA) procedures. Statistically significant main effects and interactions are presented in the Results and Discussion section.

**Irrigation data for 2006-2007 growing season.**
**Days on which irrigation was applied to plots.**

| Dates | |
|---|---|
| **-2006-** | **-2007-** |
| July 7 | July 31 |
| July 20 | August 8 |
| July 28 | August 14 |
| August 4 | August 22 |
| August 9 | |
| August 18 | |

Table 1 shows no statistical difference in 2006 between plots receiving 0, 112, and 224 kg $ha^{-1}$ N when an AWP cover crop was present. Interestingly, plots receiving no N, with winter cover crop peas present, and plots receiving 112 kg $ha^{-1}$ N, with no cover-crop present, yielded very similarly and actually produced greater yield than the plots receiving 224 kg $ha^{-1}$, with no pea cover crop, in 2006. These data imply that the winter-pea cover crop replaced as much N as delivered by the 224 kg $ha^{-1}$ application of commercial fertilizer. Plots receiving no N, but with cover crop peas, produced a grain yield of 3230.4 kg $ha^{-1}$, which was significantly different ($p=0.05$) from the plots receiving no N and no cover-crop peas, which produced a grain yield of 1980.7 kg $ha^{-1}$.

In 2007, plots receiving no N and the plots receiving 112 and 224 kg $ha^{-1}$ N were not statistically different when winter cover-crop peas were present. However, the plots receiving no N, when winter cover-crop peas were present, almost doubled the yield (2546.6 kg $ha^{-1}$) of the plots receiving no N (1391.2 kg $ha^{-1}$) when no winter cover crop peas were present. By way of generalized illustration, if N amounts are linearly related to yield, these data imply that the winter-pea cover crop potentially replaced about 80% of the mineral N needs of corn 2007 and about 63% of those needs in 2006.

Fig. 1 shows graphically what was found in 2006 and 2007 when no winter-pea cover crop was present. From the 0 N value to the 112 kg N value, a steep increase of yield is observed. This indicates that corn responded vigorously to the N application when no winter cover-crop peas were present. Fig. 2 shows the same comparison as 2006 and 2007 but with the winter-pea cover crop. From the 0 N value to the 224 kg N value, the line remains relatively flat. This linear expression indicates that the corn did not respond to the N application when winter cover-crop peas were present because all, or a great percentage, of the corn's N need was being met by the pea cover crop.

The relationship between the companion-crop cowpea seeding rate and corn yields is shown in Fig. 3. In 2006 and 2007 when companion-crop cowpeas were included, the corn yields decreased dramatically. In 2006, there was a decline as companion-crop seeding rates increased but it was not significant. However, in 2007 the decline was significant at the $p=0.05$ level of probability and the LSD value was 148. Since the difference between "0" at 3050 and "13" at 2855 was 195 kg $ha^{-1}$ (greater than the LSD), it was significantly different. These results conclude that the companion-crop cowpeas acted as a "weed" within the corn crop by essentially competing very effectively with the corn for water and nutrients.

Pea dry-matter production, nitrogen content of the dry matter, and total nitrogen produced are shown in Table 2. Tissue analysis of the dry peas showed nitrogen content (at roughly 3%) was very consistent over the two years. Dry matter and total N produced over the two years, however, varied somewhat. This may have contributed to the statistically significant yield data (Table 1) found in 2007 when analyzing plots receiving 0, 112, and 224 kg $ha^{-1}$ N where winter cover-crop peas were present. Total nitrogen produced and mineralized in 2007 was roughly 15 kg $ha^{-1}$ less than 2006 values and may have contributed to lower yield where no nitrogen was applied. Also, pea biomass produced in 2007 was 278 kg $ha^{-1}$ less than what was produced in 2006. The plants were exposed to a killing frost in on March 28, 2007, which could have contributed to the reduction of pea biomass during the 2007 growing season. Additionally, moisture levels received between January 1 and April 30, 2007 were approximately 31% lower than for the same period in 2006 (Table 3). Perhaps a combination of the hard freeze and 31% decrease in spring rainfall reduced pea biomass and therefore reduced N that could be fixed by plants and mineralized in the soil for use by the corn.

Table 3 shows the effect the cover crop had on soil moisture. In both years, the cover crop used about twice as much soil moisture, as measured in the upper 0-6 cm of soil, as did the side of the field without winter-pea cover crop. The rainfall in both years was normal, but 31% less in 2007. In any case, no decline in corn germination was seen in either year. However, both spring 2006 and 2007 had normal rainfall levels. In a dry spring, soil moisture in the winter-pea cover-crop area might be low enough to affect corn germination. In excessively wet years, it is possible that moisture taken up by the winter peas may allow cultivation or planting to take place earlier due to promotion of soil-drying conditions.

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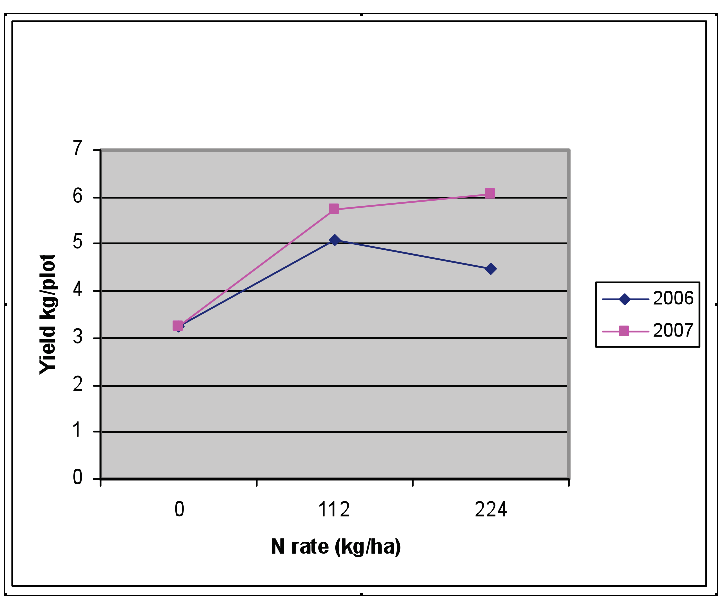


**Fig 1**. Corn yield when no winter-pea cover crop was present

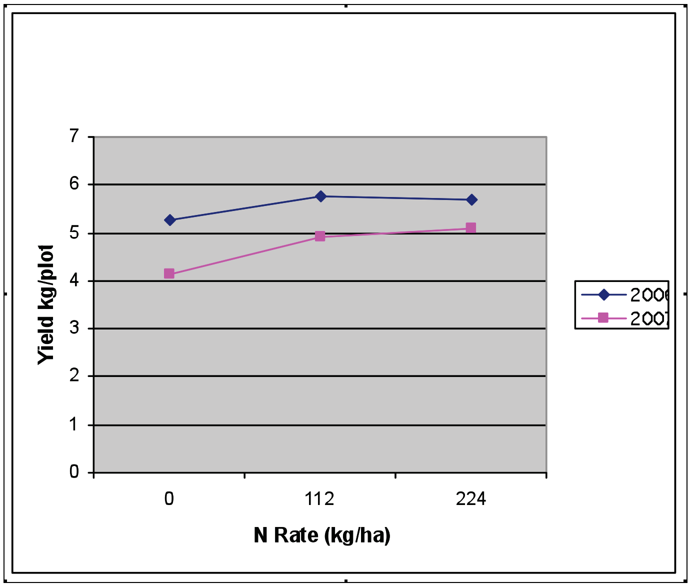


**Fig 2.** Corn yield when winter-pea cover crop was present

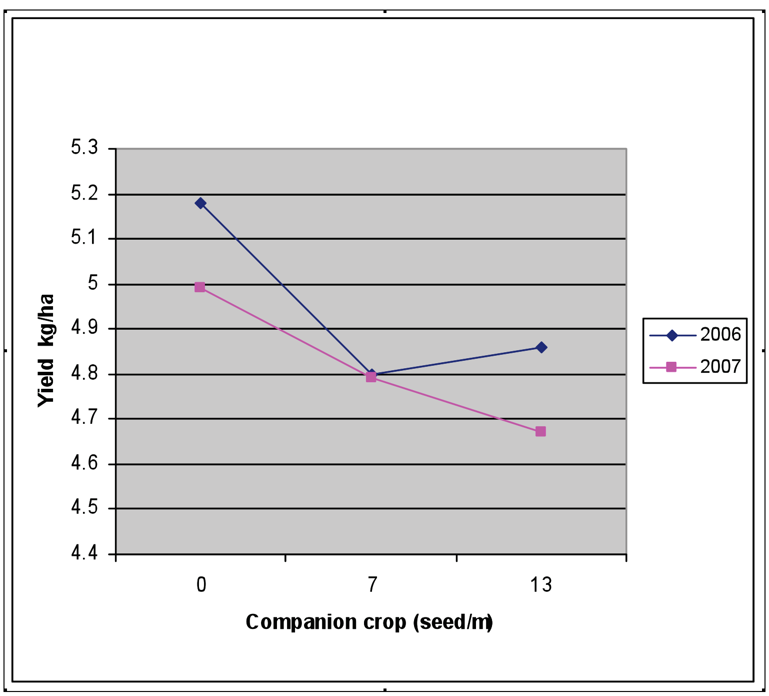


**Fig 3**. Effect of companion-crop seeding rate on corn yield
LSD (148.5) is used for comparison of treatment means in 2007, and was significant at the p=0.05 level of probability.

**Table 1. Corn yields with varying combinations of fertilizer and companion crop strategies. 2006 & 2007 plot yield values from Fayetteville, Ark.**

| Year | Level of nitrogen( kg/ha$^{-1}$) | Yield values (kg/ha$^{-1}$ ) | |
|---|---|---|---|
| | | Winter-pea cover crop | No winter-pea cover crop |
| 2006 | 0 | 3230.4 | 1980.7 |
| | 112 | 3537.0 | 3136.1 |
| | 224 | 3489.8 | 2617.4 |
| 2007 | 0 | 2546.6 | 1391.2 |
| | 112 | 3018.2 | 3537.0 |
| | 224 | 3112.6 | 3725.6 |

LSD (725.9) for comparison of means of different years at the same combination of winter peas and nitrogen treatments
LSD (750.8) for comparison means of different nitrogen treatments at same winter-pea treatment
LSD (1,213.5) for comparison of means from different levels of winter-pea treatment

**Table 2. Winter pea dry matter production and plant tissue nitrogen content for 2006, 2007**

| Year | Dry matter (kg/ha$^{-1}$) | N (%) | Total N (kg/ha$^{-1}$) |
|---|---|---|---|
| 2006 | 1210.77 | 3.07 | 44.81 |
| 2007 | 932.66 | 3.11 | 29.00 |

**Table 3. Soil moisture levels at corn planting, and total rainfall for the previous 4 months**

| Year | *Winter peas present (m$^2$/m$^2$) | Winter peas absent (m$^2$/m$^2$) | Rainfall, previous 4 month. (cm) |
|---|---|---|---|
| 2006 | 0.137 | 0.269 | 34 |
| 2007 | 0.202 | 0.388 | 23 |

*moisture samples taken just before winter peas were cut and incorporated into soil.