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Short communication

# Sweet corn significantly increases nitrogen retention and reduces nitrogen leaching as summer catch crop in protected vegetable production systems

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ABSTRACT

Nitrogen (N) leaching is a commonly reported problem in protected vegetable production in China due to poor management. To minimize soil residue N and reduce N leaching, sweet corn is often used as the summer catch crop after the winter-spring growing season. However, the effectiveness of this practice has never been systematically quantified before. Here we reported the effects of sweet corn as catch crop on soil N retention and N leaching in the greenhouse vegetable system, using the data of two $^{15}$N isotope micro-plot experiments in soil-bound greenhouse. The results showed that sweet corn removed 11.5% of total residual $^{15}$N in soil profile and kept more organic $^{15}$N by 39.8% in soil profile, compared to fallow treatment. Root activity increased nitrogen retention due to temporarily immobilizing N as organic form, thereby reducing N leaching. Interestingly, sweet corn significantly reduced N leaching in the later growing stage (August), but not in the earlier stages (July). In total, dissolved organic nitrogen (DON) accounted for 63% of total N leaching. Sweet corn significantly reduced DON leaching, but not mineral N ($N_{min}$) leaching. Hence, reducing N leaching in Chinese greenhouse must distinguish DON and $N_{min}$ sources and optimize both. Our study provides quantitative insights in N retention and leaching influenced by sweet corn as catch crop in typical Chinese greenhouse production systems, which provide guidance for searching for better catch crops in further studies.

## 1. Introduction

China has the largest greenhouse area in the world and its vegetable production in the greenhouse developed rapidly in the last three decades (Liang et al., 2015). However, most of these greenhouse productions systems were relatively low cost and the nutriment management were often not optimal (Chen et al., 2004). Overuse of chemical fertilizers in the greenhouse productions had led to serious environmental pollution, i.e. N leaching (Song et al., 2009; Ti et al., 2015) and $N_2O$ emission (He et al., 2009; Cao et al., 2015). Improving rootzone N management with furrow irrigation could reduce N fertilizer use by 50% for cucumber (Guo et al., 2008a) and by 74% for tomato (He et al., 2007). Despite of these improvements, N leaching remained problematic during the summer fallow season due to high soil $N_{min}$ residue, especially in the long term (Guo et al., 2008b, 2010).

Catch crop has been defined as a biological tool to capture residual N in the soil and reduce N leaching through prolonging the cash crop growing stage (Thorup-Kristensen et al., 2003). Several reports have demonstrated positive effects of catch crop on reducing soil N residue and N leaching in open-field rotation systems (Gabriel et al., 2012; Tuulos et al., 2015). For example, on average, non-leguminous winter catch crops could reduce N leaching by 50%, compared with none catch crop treatment (Valkama et al., 2015). Although most N leaching losses from agricultural systems occurred in the $NO_3^-$-N form, dissolved organic nitrogen (DON) leaching could be an important N loss pathway from agricultural systems as well (van Kessel et al., 2009). Many studies reported that DON loss accounted for 3–56% of total N leaching in agricultural systems (Murphy et al., 2000; Jiao et al., 2004; van Kessel et al., 2009; Huang et al., 2011). Hence, most of these studies were conducted in open-field conditions, only few studies (e.g., Min et al., 2011) investigated the effects of catch crop on soil N transformation and N leaching pathways in greenhouse systems.

Several studies reported that sweet corn, as summer catch crop, could reduce N leaching and soil mineral N and had no negative influence on vegetable yield (Guo et al., 2008b; Min et al., 2011; Yuan et al., 2015). Thorup-Kristensen et al. (2003) summarized that catch crops reduced N leaching mainly by (1) taking up soil active N during the leaching-prone fallow period with heavy precipitation and (2)

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absorbing and transpiring water and thus reducing drainage. Parkin et al. (2006) speculated that rye plants might have increased N immobilization in the organic N pools in their roots according to the N balance calculation. Thorup-Kristensen et al. (2003) reported that the use of cover crops ensures a rather stable delivery of N to the subsequent crops, regardless of winter precipitation. This suggested that soil N transformation would be influenced by the presence of living roots, resulting in changes on N fate, such as N retention and N leaching. However, these hypotheses have not been sufficiently and quantitatively investigated. Hence, the objectives of this study were to investigate the effects of sweet corn as summer catch crop on 1) the transformation and transport of residual N through the soil profile; and on 2) the loss pathway of N leaching and the fate of $^{15}$N applied in the vegetable greenhouse system.

## 2. Materials and methods

### 2.1. Study sites

Our study consisted of two experiments. One was conducted in Changping, Beijing suburbs in 2006 (Experiment 1) and the other one was in Shunyi, Beijing suburb in 2008 (Experiment 2). The climatic information such as temperature and precipitation of these two sites were shown in Fig. 1.

Both experiments were performed in the soil-bound greenhouse. The greenhouses were typical and representative in the region, constructed with clay walls and covered with polyethylene film, but without supplementary lighting and/or heating systems. Local greenhouses allow two harvests per year, i.e., the winter-spring season from February to June, and the autumn-winter season from September to January in the next year. Summer fallow season was from late June to the end of August in both experiments. A five-year old greenhouse (ground area 6 m × 72 m) was used in Experiment 1 in 2006. The soil contained 24.0 g organic matter kg$^{-1}$, 1.78 g total N kg$^{-1}$ and 62 kg $N_{min}$ ha$^{-1}$ in 0–0.3 m. The soil bulk density ranged from 1.42 to 1.62 g cm$^{-3}$ and the soil was of a silty loam texture in the top 1.8 m. Experiment 2 was conducted in a 10-years old greenhouse (8 m × 71 m) in Shunyi county from 1 Jul to 25 Aug (fallow period) in 2008. Tomato was the preceding vegetable crop. The soil contained 16.8 g organic matter kg$^{-1}$, 1.4 g total N kg$^{-1}$ and 306 kg $N_{min}$ ha$^{-1}$ in 0–0.3 m, respectively. The soil bulk density ranged from 1.31 to 1.47 g cm$^{-3}$ and the soil was of a sandy loam texture in the top 0.9 m.

### 2.2. Experiment 1

$^{15}$N micro-plots was used to explore the influence of sweet corn planting on the fate of residual $^{15}$N left by proceeding cucumber in Changping. Cucumber growth period was from 15 Feb to 18 June. Sweet corn was grown as catch crop from 27 Jun to 2 Sept. Six main field plots (Size: 4.8 m × 5.5 m) were established in cucumber growth period. After the final harvest of cucumber, sweet corn planting and fallow treatments were designed and arranged in the six main plots in the summer fallow season. $^{15}$N-labeled micro-plots (Size: 1.1 m × 1.1 m) were separated and setup in the six field plots. Six cucumber seedlings were transplanted in each micro-plot. Before transplanting, 146 kg N ha$^{-1}$of chicken manure, 270 kg $P_2O_5$ ha$^{-1}$of calcium superphosphate and 120 kg $K_2O$ ha$^{-1}$ of $K_2SO_4$ was broadcast as basal fertilizer, and then the field was ploughed into 0.25 m deep. The application of 280 kg $K_2O$ ha$^{-1}$of $K_2SO_4$ was split in seven times as topdressing with the furrow irrigation in the cucumber season.

In total, 130 kg N ha$^{-1}$ as $^{15}$N-urea (10% $^{15}$N abundance) was evenly applied in micro-plots on 4 May 2006 in the middle of cucumber growing period, and there was no N topdressing in all micro-plots until final harvest of cucumber. All of micro-plots were irrigated at the rate of 100 mm for eight times with the interval of 5 days after $^{15}$N-urea was applied in cucumber season.

After the final harvest of cucumber, sweet corn seedlings at the three-leaf stage were transplanted into the main plots and micro-plots with 0.6 × 0.3 m spacing (six seedlings per micro plot) on 29 Jun 2006 without any tillage after the cucumber harvest. The greenhouse plastic cover was removed during July 21–Sept 8 to avoid excessive temperature inside the greenhouse during summer. No irrigation was

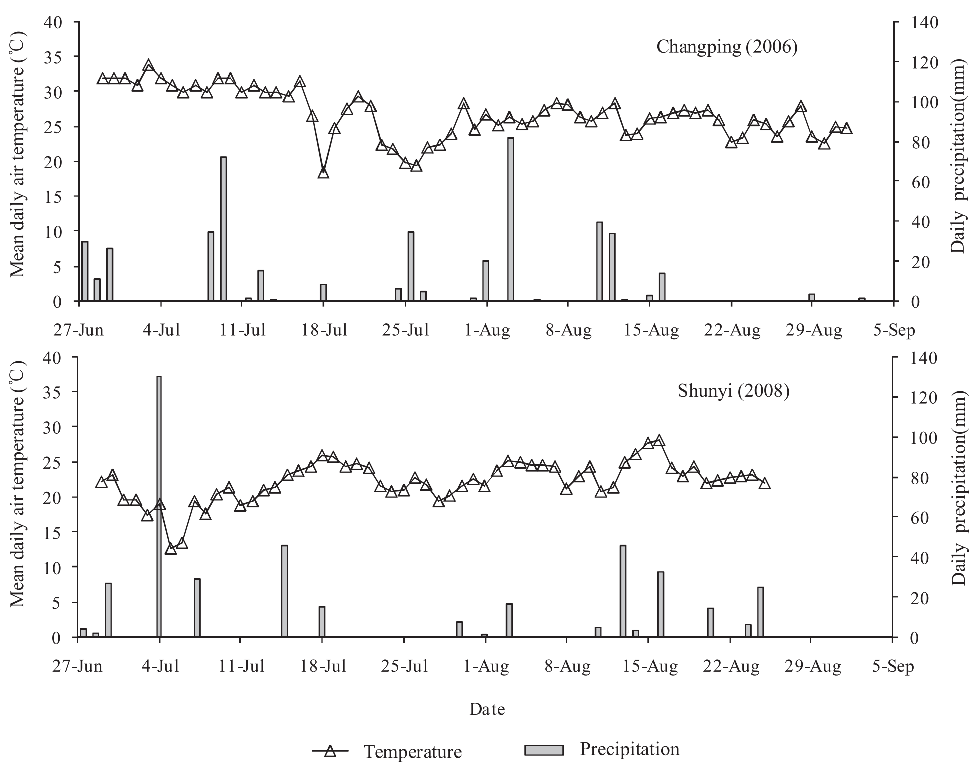


**Fig. 1.** Mean daily air temperature and precipitation during fallow period in the greenhouse in Changping (2006) and Shunyi (2008), Beijing.