Nitrogen Management in Strawberry Production

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Nitrogen management in perennial strawberries is different than with most other fruit crops. Generally, nitrogen is provided to fruit crops in early spring, just prior to the flush of vegetative growth that ensues as buds break dormancy. It is important for woody plants to have sufficient N in spring because without adequate shoot growth, the wood on which flower buds form is reduced. Although low N might not affect yield in the current year, it can affect yield in subsequent years.

"We found that increasing Carbon supply during the previous growing season increased root size, starch content and concentration, leading to greater yield the following year Plants with higher N reserves also produced greater biomass than those with lower N reserves,. The potential exists to economically increase yields in some cases by using fall foliar fertilization in October (once vegetative growth has ceased) provided that the plant's carbohydrate status is adequate. This supplementation method can increase reserve N without the environmental risk from soil-applied fertilization in autumn or the detrimental effect on fruit quality from spring fertilization."

Strawberries do not have shoots in the typical sense. The shoots of strawberry are only about an inch long, and from those shoots (crowns) leaves, runners and flower buds develop – depending on temperature and day length. In perennial strawberry, flower buds initiate in fall and develop in spring. Fruiting occurs very early during the growing season. Runnering, which is the most significant vegetative activity, occurs after fruiting in summer when day lengths are long and temperatures are warm.

Given this growth pattern, growers have found that N fertilizer is best applied just after fruiting but before the flush of summer runnering.

Although strawberry plants are small, they are not efficient at sequestering N from the soil. Typical recommendations for summer-applied N are about 70 lbs/acre (almost any source will do.) Although this may seem high for a small perennial crop, strawberries in Florida can receive 400 lbs/acre over the course of a growing season. Research has shown that strawberries actually use about 100 lbs N/acre per year, but significantly more must be applied to meet this need, especially on sandy soils that contain little N and where leaching is high.

In the Northeast, residual N in the soil in the form of organic matter can supply a significant amount of N beyond what is applied by the grower. So, even though the total requirement may be 100 lbs/acre, more than this is usually not required from fertilizer because the remainder can be supplied from soil sources. Typically, for established strawberries, growers apply 70 lbs/acre in summer and another 30 lbs/acre in early September – for a total of 100 lbs/acre. Organic strawberry growers face a challenge of providing sufficient N to accommodate vegetative growth after harvest. As a consequence, many organic growers only fruit their planting once, then incorporate N prior to the next planting. Leaf analysis can be used to determine if N levels are adequate – a range between 2 and 3% is satisfactory in leaves tested in mid-summer. (New plantings are fertilized differently – usually two or three applications of 30 lbs each throughout the first growing season, beginning a few weeks after planting.)

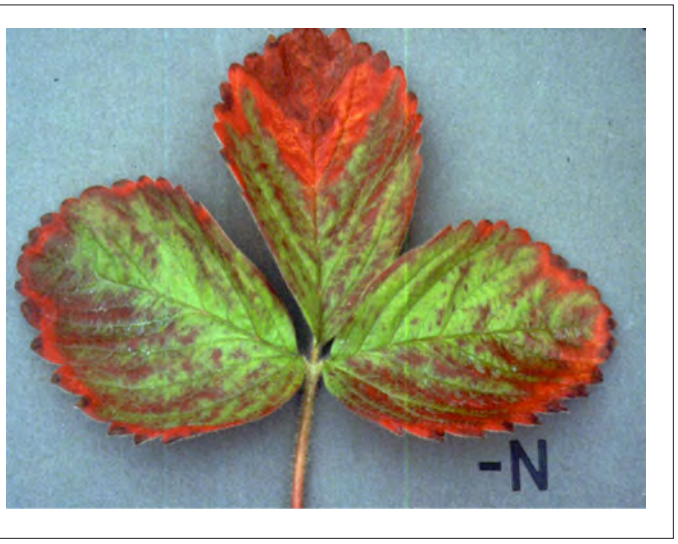

Photo: Nitrogen deficiency symptoms in strawberry.

Many growers, concerned about poor growth in spring, will apply N before flowering. Our research has shown that more than about 30 lbs/acre at that time can induce excessive vegetative growth and create conditions favorable for gray mold. Wilcox and Pritts found this phenomenon in each of three years when they examined different rates of spring-applied N. So how should growers ensure that spring growth is not limiting? Our research has shown that the answer is to ensure that both fall N and carbohydrate reserves are adequate and in balance with each other.

At the end of the growing season before the onset of dormancy, many deciduous plants, including perennial strawberries, accumulate carbohydrates and N and use these reserves to support initial growth in the spring. As spring growth begins, both reserve carbohydrate and N concentrations decrease as the plant uses these to support flowering, fruiting, and the development of new leaves. Growers will want to ensure that neither of these is depleted before strawberry plants can begin

to replenish this supply in spring.

Carbohydrate reserves in fall can be either increased or decreased by fertilizing with N. When Rubisco (a photosynthetic enzyme that accounts for a large portion of plant N) is limiting, an increase in N can lead to increased CO_2 assimilation since more Rubisco will be manufactured. In contrast, if Rubisco is not limiting, further increases in N availability can decrease carbohydrate status since carbohydrate is required to incorporate N into the plant. Carbohydrate status also can be increased directly through exposure of plants to elevated levels of CO_2. Exposure to high CO_2 stimulates net C assimilation and leads to an increase in carbohydrate levels in leaves. Our research has found that too little N relative to carbohydrate results in poor performance, as does too much N.

Experiments

Differential N fertigation (0 through 20 mM N) was applied to potted strawberries during the growing season and a supplemental foliar urea application (3% urea applied to runoff in early October) was applied to a portion of the plants in the fall to modify reserve N just prior to dormancy. In a second experiment, carbon dioxide (CO_2) enrichment during the growing season, with and without soil and foliar N application in the fall, was used to vary C and N reserves.

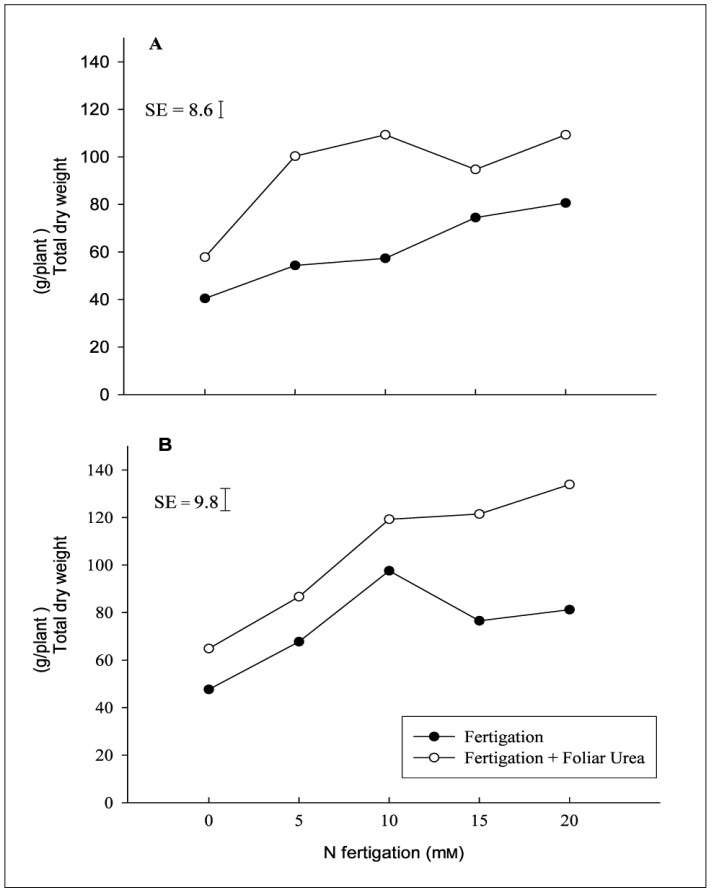

Figure 1. Total strawberry plant dry weight (g/plant) in July 2002 in relation to nitrogen (N) fertigation and foliar urea application in 2001, with no spring applied N (A) or supplemental spring N (B) in 2002. Effect of N fertigation, P < 0.0001; N foliar urea, P < 0.0001; spring N and interactions were not significant.

Results and Discussion

Our experiments showed that perennial strawberry plants responded to increasing N supply with greater growth (Figure 1), more total N reserve (Figure 2) but lower starch reserves (Figure 3) especially in roots. When plants had a low to moderate N status, increasing the N supply in fall through a foliar application resulted in increased yields the following spring (Fig 4). However, there is a limit to the yield increases obtained with N fertigation and supplementation. Yields were not increased when total plant N in spring exceeded about 100 mg/plant (Figure 5). In fact, fall urea supplementation in high N plants (those fertigated with 15 or 20 mM N) resulted in yield reductions (Figure 4). Others have shown that high rates of ammonium fertilizer solution, coupled with high temperatures, resulted in death of strawberries due to depletion of sugars from N assimilation and respiration.

A fall foliar N application decreased the C/N ratio, but this did not negatively impact yield so long as plant N status was not too high. Our results indicate that a foliar urea application in the fall is effective at increasing yield of strawberry plants if carbohydrate status is adequate and if plants were not heavily fertilized during the growing season.

In the first study, spring N applications were not effective at increasing yield significantly in the current year, suggesting that sufficient reserve N was present to sustain growth and fruiting through mid-summer. In the other study, increases in yield were measured with supplemental spring N, but even when a 50% growth response to spring N was observed, the

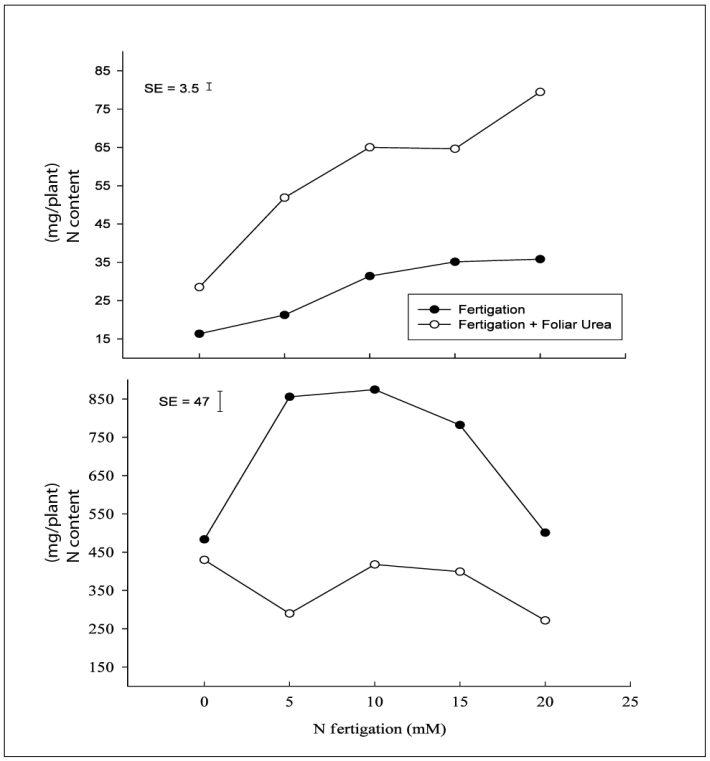

Figure 2. Effect of nitrogen (N) fertigation in summer and foliar urea in autumn on N and total nonstructural carbohydrate (TNSC) content (mg/plant) in strawberry root tissue the following spring (Mar. 2002). Each value is a mean of six plants. Effect of N fertigation, P<0.0001; N fertigation + foliar urea, P<0.0001; Interaction P<0.0001.

yield response was only 12%, suggesting that it is mostly fall-assimilated N that is used for flower and fruit development. Spring-applied N influences vegetative plant parts much more than reproductive parts. Applying spring N to compensate for low N reserves is not efficient, and can be detrimental to fruit quality.

Strawberry plants accumulated biomass in response to CO_2 enrichment (88.1 vs. 106.2 g/plant dry weight for -/+ CO_2 enrichment, respectively), especially in below ground plant parts (43.2 vs. 52.3 g/plant). This has been observed in other studies and is likely the result of plants increasing their sink capacity by developing more storage tissue in roots. In addition, strawberry root activity is known to continue well into the fall while above ground parts reduce their growth and lose some leaf biomass. Carbohydrates, especially starch, were reallocated from roots and crowns to leaves and fruit, from early spring through harvest. The larger root system with its greater C reserves that resulted from CO_2 enrichment led to larger plants and higher yields. Across all treatments, C reserves were correlated with yield (Figure 6), suggesting that C reserves limit strawberry productivity.

Summary

To conclude, vegetative growth and yield of strawberries are dependent on both C and N reserves. We found that increasing C supply during the previous growing season increased root size, starch content and concentration, leading to greater yield the following year - perhaps by promoting flower bud differentiation in early spring. Yield responses were a reflection of fruit numbers rather than size, and spring N did not have a large effect on yield, further suggesting that it is flower bud differ-

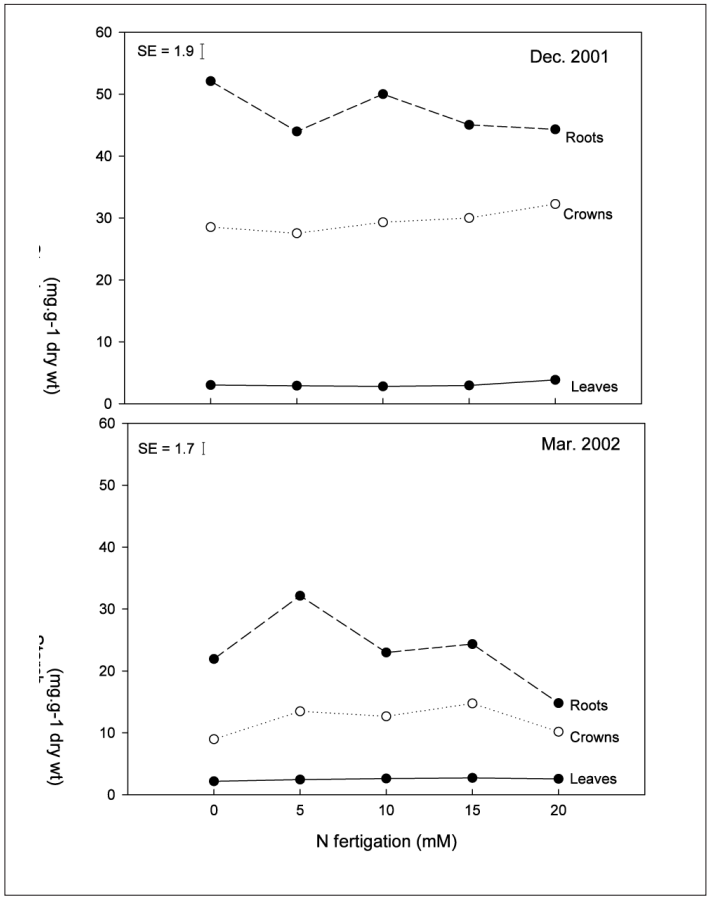

Figure 3. Nitrogen (N) concentrations (per dry weight, DW) in strawberry plant parts over the winter in relation to N fertigation during the previous summer. Each value is a mean of six plants. Tissue type P<0.0001 in all cases; N fertigation in December and March, P<0.01 and 0.0001, respectively; no significant interactions.

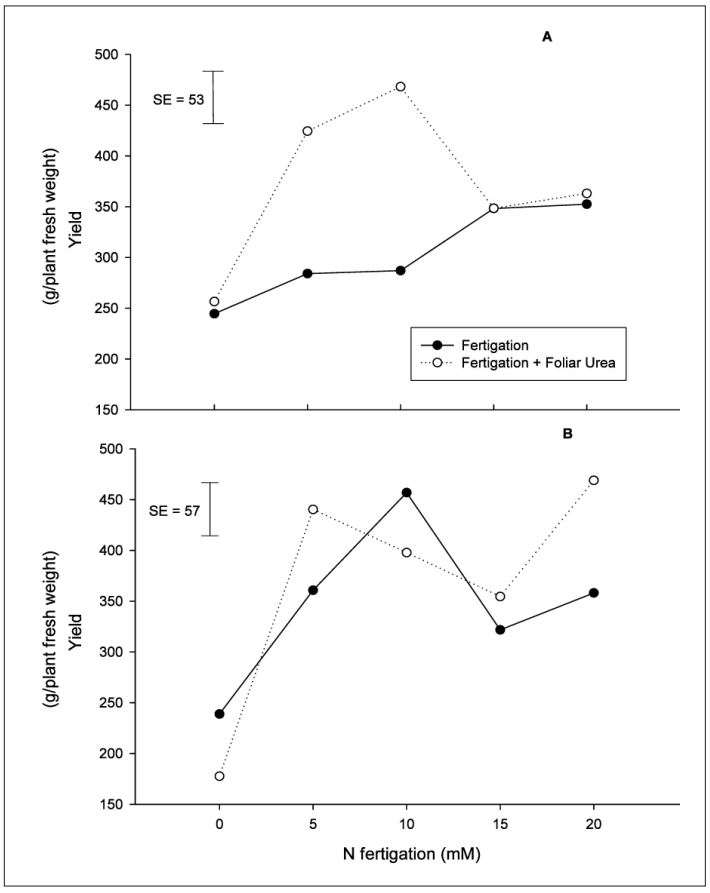

Figure 4. Strawberry yield in relation to previous year's nitrogen (N) treatments. No spring N (A) and 10 mM spring N (B). Each value is the mean of six plants. Effect of N fertigation (A) P<0.08; (B) P<0.008; effect of N fertigation + foliar urea (A) P<0.04; (B) is NS; no significant interactions.

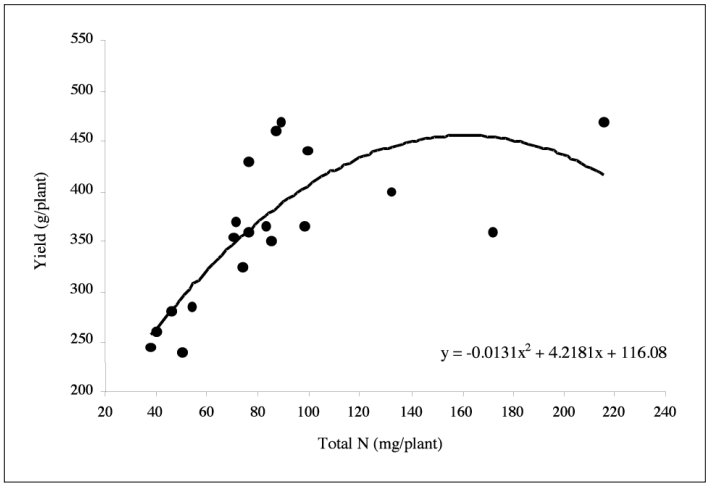

Figure 5. Relationship between strawberry yield and total plant nitrogen (N) (mg/plant) across all treatments. Each value is a mean of six plants.

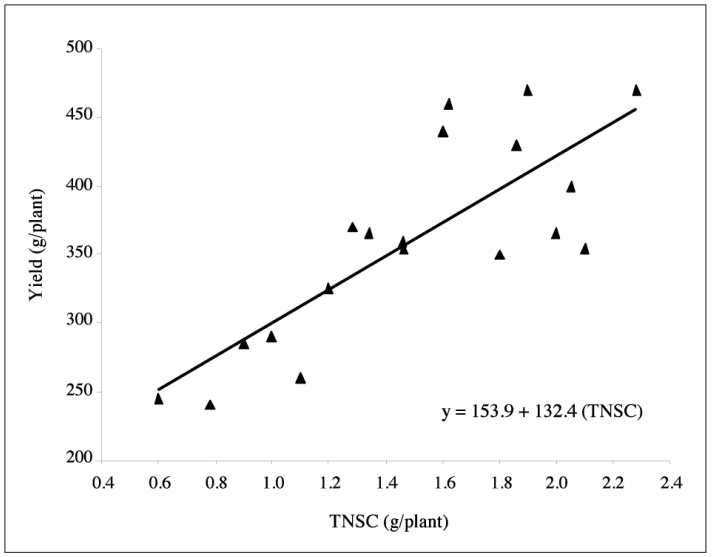

Figure 6. Yield of strawberries appears to be linearly related to plant carbohydrate status. Data are combined across treatments.

entiation that is affected by C and N reserve status. Plants with higher N reserves also produced greater biomass than those with lower N reserves, but this did not always translate into higher yields. At very high N levels, both total nonstructural carbohydrates (TNSC) and yields were reduced. N content of about 100 mg/plant at harvest was optimal. Plants with excessive N were larger and lush, but had no additional fruit.

The potential exists to economically increase yields in some cases by using fall foliar fertilization in October (once vegetative growth has ceased) provided that the plant's carbohydrate status is adequate. This supplementation method can increase reserve N without the environmental risk from soil-applied fertilization in autumn or the detrimental effect on fruit quality from spring fertilization. Similar results have been found for apple, sweet cherry and grape.

Marvin Pritts is a research and extension professor who leads Cornell's program in berry crop management. **Laura Acuña Maldonado** was a graduate student who completed her MS degree under Marvin Pritts.