Changes with season of nutrients in salad greens grown in high tunnels

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Growth and composition of leafy vegetables varies with season or time of year. This seasonal variation is related to changes in light and temperature that affect metabolism in leaves and roots, and the rate of chemical transformation of nutrients in the soil. The variation of nutrient availability with season may depend on whether the crop is grown with nitrate-based fertilizer or organic fertilizer. Similar yields are generally obtained with organic and inorganic fertilizer. In field trials, compost or mineral fertilizer gave equal yield for lettuce, cabbage, carrots, tomatoes, and peppers. Sometimes compost amendment increases the concentration of nutrients in leaves, compared to inorganic fertilization. Different species of salad greens react differently to fertilizer. Nitrate in mustard and turnip greens rose with N application up to 100 lbs acre, whereas nitrate in lettuce reached a maximum at 50 lbs, and composition of kale did not have a simple response to applied N. Although the leaf nitrogen did not vary among lettuce, spinach, and cabbage when grown with little or no fertilizer, it varied substantially among these species when excess N fertilizer was applied.

Because high tunnels allow growth later in the year, and at times when there is more extreme variation of day to night temperature, growth in high tunnels may exaggerate seasonal variation in composition of lettuce and other salad greens. I examined the growth and composition of crops grown in high tunnels and harvested at approximately one month intervals from September to June. Seven species of greens were grown either with organic fertilization, namely leaf compost amended with cotton seed meal, or inorganic fertilization, namely perlite watered with a complete nitrate-based nutrient solution.

Environment

Day-time average temperatures in high tunnels ranged from 40 to 70 ^{o}F in winter to 90 ^{o}F or more in summer. Night-time temperatures were below freezing from late November to early March. These cold temperatures were the primary limitation to growth in winter. Night-time temperatures in the high tunnels were only 2 or 4 ^{o}F degrees warmer than ambient, whereas day-time temperatures were 20 ^{o}F warmer than ambient throughout the year. Day-time temperatures were correlated with sunlight, but on a weekly basis, the maximum and minimum temperature lagged about one month behind maximum and minimum sunlight integral. Temperatures were warmer in fall than in spring at a given light level.

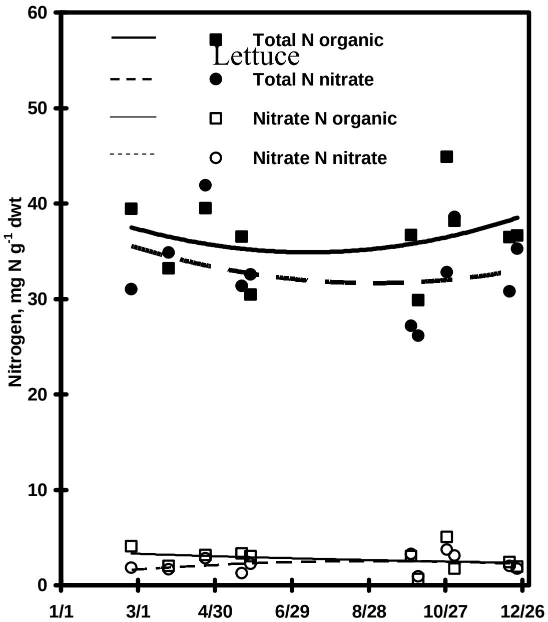
Growth

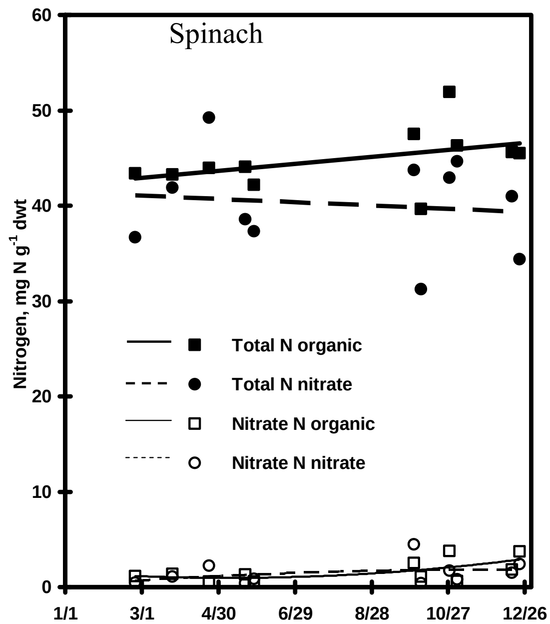
Growth in high tunnels was most rapid in May and September, 17 to 21% per day averaged over all species tested. Reasonable growth rates were also seen in April and October, 12 to 14% per day. Growth in the open field was much slower at this time of year, typically 5 to 10% per day. Growth in high tunnels slowed substantially in the fall, from about 15% in early October to 5 to 7% in late December. Quality of leaves was good, except when plants experienced sudden extreme cold after a period of mild weather. Growth in winter was extremely slow, between 0%

and 7% per day. Plants survived the cold, but leaves tended to desiccate, or have tip burn or translucent patches, and stem tissue turned brown. Some salad greens tended to bolt quickly in the heat of May and September.

Tissue composition of leaves

Total nitrogen and nitrate content as a function of fertilizer and time of year for:





In contrast to the wide variation in growth rate with time of year, elemental composition of leaves of salad greens varied little with season. Nitrate did not accumulate to high levels in leaves of salad greens when grown in winter under low light, a phenomenon often observed in heated greenhouses. Although nitrate-based fertilizer resulted in a dip in total leaf nitrogen for lettuce in early fall, no seasonal response occurred with organic fertilizer (Figure 1). There was a similar trend with time of year for total reduced nitrogen in spinach (Figure 2). The amount of nitrate and the seasonal variation in nitrate was much smaller than that for total reduced nitrogen in both lettuce and spinach. Cool air and soil in the unheated high tunnels may decrease uptake of nitrate by plants, and compensate for slow growth.

Cool temperature may restrict uptake of other nutrients. Concentrations of potassium and calcium varied more with season than did that of nitrogen. However, the variation with time of year of these nutrients had a pattern that was not simply related to seasonal pattern in growth rate or environment. Differences in leaf composition due to fertilizer often occurred in a particular species and at a particular time of the year. This was true for total nitrogen and calcium. The difference in nitrogen in lettuce due to fertilizer only occurred in early fall and it may be related to a high availability of nitrate in the organic root medium at this time of year. Arugula also had particularly high nitrate when grown with organic fertilizer in early fall, 10 to 12 mg g^{-1} compared to about 5 mg g^{-1} at other times of year. Fertilizer affected nitrate in kale only in spring, when leaf nitrate was about 10 and 5 mg g^{-1}, with nitrate-based compared to organic fertilizer, respectively. Spinach had higher calcium with nitrate-based than with organic fertilizer in the fall, but not in the spring. These differences among species, in time when form of fertilizer exerted an effect on composition, suggest that environmentally sensitive processes within the plant, rather than in the root medium, were responsible for differences in leaf composition due to fertilizer.

Nitrate and Ammonium in the Root Medium

In part, these results could be due to seasonal and fertilizer differences in the available concentrations of the various nutrients in the root medium. More nitrate could be extracted from compost with cottonseed meal than from perlite with nitrate-based fertilizer. For both fertilizers, more nitrate could be extracted in fall than in the spring. Extractable nitrate concentrations with organic fertilizer were about 100 and 45 ppm in a 1:1 extract, in fall and spring, respectively, compared to 70 and 30 ppm N with nitrate-based fertilizer. Extractable ammonium was much lower than nitrate. Organic fertilizer resulted in about 2 to 3 ppm ammonium-N in the root medium. The medium with nitrate-based fertilizer always had less than 1 ppm ammonium-N.

Growth was not related to nitrate availability in the root medium. Greens grew quickly in late spring, when the lowest concentrations of nitrate were extracted from the root medium. There was more nitrate available in fall and early spring, than in late spring, which suggests that nitrate availability did not limit growth except possibly in late spring. The root medium and leaf tissue nitrogen reported here suggest that fertilization was not excessive. The values of leaf nitrate are at the low end of the range reported in field studies of salad greens in Missouri and in England.

Further reading.

Gent, M.P.N. 2002. Growth and Composition of Salad Greens as affected by Organic Compared to Nitrate Fertilizer and Environment in High Tunnels. J. Plant Nutrition 25:981-998

Gent, M.P.N. 2005. Effect of genotype, fertilization, and season on free amino acids in leaves of salad greens grown in high tunnels. J. Plant Nutrition 28:1-14