Evaluating Hairy Vetch Residue as Nitrogen Fertilizer for Tomato in Soilless Medium

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Abstract. The ability of hairy vetch (Vicia villosa Roth) residue (100 g/plant) to supply N and to increase yields of tomato (Lycopersicon esculentum Mill.) was compared with that of N fertilization (0, 4.1, and 8.2 g/plant N) in a medium containing a mixture of 3 perlite : 1 vermiculite in a greenhouse and a lathhouse. Hairy vetch residue did not interact with N fertilization in affecting tomato yield and medium N concentration. In the greenhouse, leaf dry weight, leaf and stem N uptake, total (fruit + stem + leaf + root) dry weight and N uptake of tomato, and NH4– and inorganic N concentrations in the medium at transplanting were significantly greater with than without residue. In the lathhouse, tomato number, fresh and dry yields and N uptake, leaf, stem, and root dry weights and N uptake, root length, total dry weight and N uptake of tomato, and NH4–, NO3–, and inorganic N concentrations in the medium at transplanting, and inorganic N at harvest were greater with than without residue. Nitrogen fertilization increased fruit number, fresh and dry yields and N uptake, stem, leaf, and root dry weights and N uptake, root length, and total dry weight and N uptake. The residue was as effective in increasing fresh fruit yield, total dry weight, and N uptake as was 4.4 to 7.9 g/plant of N fertilizer. Tomato yield and N uptake per unit amount of N supplied was greater for the residue than for N fertilization, suggesting that hairy vetch residue can be effectively used as N fertilizer for tomato production.

Hairy vetch, a legume, fixes N from the atmosphere. Because of its high N concentration and low C:N ratio, hairy vetch residue (HVR) decomposes rapidly in the soil (Kuo et al., 1997; Stute and Posner, 1995) and supplies a substantial amount of N to the succeeding crop (Frye et al., 1988; Hargrove, 1986; Kuo et al., 1996, 1997). The residue can supply 50% to 100% of the N requirement of the succeeding crop (McVay et al., 1989), and increased crop yields as much as did 66 to 200 kg·ha–1 of N fertilizer (Sainju and Singh, 1997). Cover crops of hairy vetch increased tomato yield (Abdul-Baki and Teasdale, 1993; Abdul-Baki et al., 1996; Sainju et al., 1999). Kelly et al. (1995) found that increased tomato production later in the growing season was greater with hairy vetch than with polyethylene mulch or bare soil, thereby increasing monetary returns even during adverse climatic conditions.

Besides supplying N and increasing crop production, a cover crop of a hairy vetch can improve soil and water quality by reducing erosion, increasing organic matter, and reducing NO3– leaching to the groundwater (Sainju and Singh, 1997). Nitrogen is released more slowly by HVR than by N fertilizer and the release is better synchronized with crop N demand (Stute and Posner, 1995).

Although HVR increases tomato production, the residue alone may not produce sustainable yields of fresh market fruits; additional N fertilization may be needed to produce such yields. Since N is one of the most limiting nutrients for crop production, the interactive effects of HVR and N fertilization on tomato yield must be evaluated. The concentration of soil N may also influence the effect of the HVR on tomato production. Therefore, the test must be conducted in a soilless medium devoid of N. We used a mixture of 3 perlite:1 vermiculite with or without HVR and N fertilization for growing tomatoes in a greenhouse. To expose plants to atmospheric conditions as similar to those in the field, we also grew them in the same medium in a lathhouse in the summer. Spaces between laths maintained temperature and moisture levels similar to those outside the house. However, shading reduced the amount of sunlight.

We hypothesized that HVR could supply N and produce tomato yields similar to that produced by 50% to 100% of the recommended level of N fertilization. Our objective was to evaluate the HVR as N fertilizer for supplying N and increasing tomato production in a medium containing a mixture of 3 perlite:1 vermiculite devoid of N.

Materials and Methods

Treatments. The treatments consisted of two levels of residue (hairy vetch vs. none) and three levels of N (0, 4.1, and 8.2 g/plant). The treatments were arranged in a factorial design with three replications. The amount of HVR (100 g) applied to each pot or tomato plant was based on the equivalent amount of cover crop biomass produced per unit area in the field at the Fort Valley State Univ. farm in Georgia (4 kg·ha–1 residue × 0.25 m2 surface area and 30 cm depth of the pot). Similarly, the maximum amount of N fertilization applied to each plant was based on the recommended dose for tomato in central Georgia (180 kg·ha–1 N) (Univ. of Georgia, 1995).

Greenhouse. On 10 Feb. 1998, perlite and vermiculite were mixed at a 3:1 ratio and 5 kg of the mixture was transferred to each 19-L polyethylene pot. Field-grown hairy vetch at vegetative stage (103 d after planting) was harvested at 2 cm above the ground, washed thoroughly with water to remove soil particles, oven-dried at 60 °C for 3 d, and ground to pass a 1-mm screen. For the residue treatment, hairy vetch (N concentration, 30.2 ± 1.3 g·kg–1) residue was mixed thoroughly with the perlite and vermiculite at a rate of 100 g/pot. All pots, with or without residue, were moistened with water, covered with plastic sheets to reduce evaporation, and stored for 2 weeks in the greenhouse to allow N release from the residue, the perlite and vermiculite mixture, or both before planting tomatoes. The temperature in the greenhouse was maintained at 23 °C during the day and at 16 °C during the night during residue incubation and throughout tomato growth.

On 24 Feb. 1998, two 5-week-old tomato (cv. Sunbeam) seedlings were transplanted in the center of each pot. After 2 weeks, one plant was thinned, leaving only one plant per pot. For the first week after transplanting, 50 mL of starter solution, containing 3 g·L–1 each of N, P, and K, was applied at one time to each plant for rapid establishment. Although this added 0.15 g N to each pot, we assumed that this would not significantly alter the effect of the treatments on growth. Nitrogen fertilizer (NaNO3, 16% N) was applied three times at 3-week intervals after transplanting. The NaNO3 was used because it has a low N concentration and releases N more slowly than do NH4NO3, (NH4)2SO4, or urea. Although Na+ is toxic to tomato, we found that Na+ did not influence tomato growth. All other nutrients were applied in Hoagland’s solution using water from the drip irrigation system. Irrigation was turned on for 30 min with an automatic timer 1 or 2 times a day, depending on the moisture content of the medium. The concentration of the nutrients (mg·L–1) in the solution were: P = 125, K = 234, Ca = 200, Mg = 48, S = 126, Fe = 5.1, B = 0.5, Zn = 0.05, Cu = 0.02, and Mo = 0.01. On 6 Apr. 1998, tomato plants were sprayed with malathion (0.0-dimethyl phosphorodithioate diethyl mercaptosuccinate) at the rate of 6 g·L–1 to control aphids.

From May to June 1998, fruits were harvested regularly as the color turned from green to pink. Fruits were weighed, cut into slices, oven-dried at 60 °C, weighed again, and ground to pass a 1-mm screen for N analysis. After all
fruits were harvested, plants were cut 2 cm above the surface of the medium, separated into leaves and stems, oven-dried, weighed, and ground. Similarly, roots were separated from the medium, washed thoroughly with water, and stored at 4°C. After root length was measured, roots were oven-dried, weighed, and ground. Samples of the medium were taken from the surface to the bottom of the pot with a push tube (2 cm i.d.) at three places before tomato transplanting and after harvest. Samples were mixed within a pot, air-dried, and ground to pass a 2-mm screen for N analysis.

**Laboratory analysis.** The root length of tomato in each pot was determined by using Agvision (Decagon Devices, Pullman, Wash.). The N concentration in fruits, leaves, stems, and roots was determined by the H2SO4–H2O2 method (Kuo et al., 1997). The N uptake by each of these components was determined by multiplying the dry weight by N concentration.

**Results**

**Tomato fruit yield, N concentration, and N uptake.** Tomato fruit number, fresh and dry yields, and N uptake were significantly greater with than without HVR in the lathhouse (Table 1). Fruit number, fresh and dry yields, and N uptake increased with increasing N fertilization rate in both the greenhouse and the lathhouse. Fruit fresh and dry yields and N uptake were greater with 8.2 than with 0 and 4.1 g/plant N in the greenhouse, and were greater with 4.1 and 8.2 than with 0 g/plant N in the lathhouse. Fruit N concentration was not influenced by the residue and N fertilization treatments. Similarly, the interaction of residue and N fertilization was nonsignificant for fruit number, fresh and dry yields, N concentration, and N uptake.

**Nitrogen concentration in the medium.** The NH4+ and inorganic N concentrations in the medium at transplanting were greater than without HVR in the greenhouse but N concentration at harvest was not affected (Table 4). In the lathhouse, N concentration in the medium at transplanting and inorganic N concentration in the medium at harvest were greater than without HVR. The N concentration in the medium at transplanting and harvest was not influenced by N fertilization in both the greenhouse and lathhouse. Interaction of residue and N fertilization was also nonsignificant for N concentration in the medium.

**Discussion**

The promotive effect of HVR on tomato fruit number, yield, and N uptake in the greenhouse and lathhouse was not influenced by the treatments. In addition, N uptake was greater with 8.2 than with 0 g/plant N in the lathhouse. Root length and dry weight were greater with than without residue both in the lathhouse and the greenhouse. In addition N uptake was greater in the lathhouse (Table 3). Similarly, root length, dry weight, and N uptake were greater with 8.2 than with 0 g/plant N in the lathhouse. Nitrogen concentration of stems, leaves, and roots was not influenced by the treatments (Table 2 and 3). The residue × N fertilization interaction was also nonsignificant for stem, leaf, and root dry weights, N concentration, or N uptake.

**Table 1.** The effects of hairy vetch residue and N fertilization on number, fresh and dry yields, N concentration, and N uptake of tomato fruits. Plants were grown in a mixture of 3 perlite : 1 vermiculite in the greenhouse and lathhouse.

| Treatment                  | Yield | N concentration | N uptake |
|----------------------------|-------|-----------------|----------|
|                            | Fresh | Dry | N concn | g/plant | g/kg | mg/plant |
| **Greenhouse**             |       |     |         |         |      |          |
| Residue                    | –     | 9.8 a | –       | 869 a   | 63.2 a | 13.0 a   | 817 a     |
| –                          | 8.3 a | 815 a | 58.8 a  | 12.2 a  | 706 a  |          |
| N fertilization (g/plant)  |       |     |         |         |      |          |
| 0                          | 6.3 b | 501 c | 38.6 c  | 11.8 a  | 479 c  |          |
| 4.1                        | 8.5 b | 854 b | 59.9 b  | 12.5 a  | 813 b  |          |
| 8.2                        | 12.3 a| 1172 a| 84.4 a  | 13.6 a  | 992 a  |          |
| Interaction                | NS    | NS  | NS      | NS      | NS     |          |
| **Lathhouse**              |       |     |         |         |      |          |
| Residue                    | –     | 9.3 a | 1018 a  | 64.3 a  | 37.4 a | 2389 a   |
| –                          | 3.7 b | 496 b | 31.6 b  | 38.1 a  | 1196 b |          |
| N fertilization (g/plant)  |       |     |         |         |      |          |
| 0                          | 4.3 b | 423 b | 28.1 b  | 38.8 a  | 1072 b |          |
| 4.1                        | 6.3 ab| 865 a | 55.9 a  | 36.3 a  | 2053 a |          |
| 8.2                        | 8.8 a | 983 a | 59.8 a  | 38.1 a  | 2252 a |          |
| Interaction                | NS    | NS  | NS      | NS      | NS     |          |

*Mean separation within columns and sets by the least square means test, P ≤ 0.05.

*Nonsignificant.
Table 2. The effects of hairy vetch residue and N fertilization on dry weight, N concentration, and N uptake of tomato stems and leaves, and total (fruits + stems + leaves + roots) dry weight and N uptake. Plants were grown in a mixture of 3 perlite : 1 vermiculite in the greenhouse and lathhouse.

| Treatment          | Greenhouse     | Lathhouse   |
|--------------------|---------------|-------------|
|                    | Dry wt (g/plant) | N concn (g·kg⁻¹) | N uptake (mg/plant) | Dry wt (g/plant) | N concn (g·kg⁻¹) | N uptake (mg/plant) |
| Residue            |                |             |                    |                |             |                    |
| +                  | 37.1 a         | 6.7 a       | 247 a              | 32.8 a         | 11.5 a       | 393 a              | 135.7 a           | 1490 a           |
| –                  | 30.4 a         | 6.5 a       | 195 b              | 24.8 b         | 11.8 a       | 284 b              | 116.2 b           | 1213 b           |
| N fertilization (g/plant) |         |             |                    |                |             |                    |                |                |
| 0                  | 21.6 c         | 6.6 a       | 143 c              | 17.5 c         | 11.6 a       | 200 c              | 79.5 c            | 849 c            |
| 4.1                | 34.3 b         | 6.8 a       | 228 b              | 28.3 b         | 13.6 a       | 313 b              | 125.0 b           | 1385 b           |
| 8.2                | 45.4 a         | 6.4 a       | 291 a              | 40.6 a         | 12.2 a       | 502 a              | 173.4 a           | 1823 a           |
| Interaction        | NS             | NS          | NS                 | NS             | NS           | NS                 | NS               | NS              |

Table 3. The effects of hairy vetch residue and N fertilization on length, dry weight, N concentration, and N uptake of tomato roots, and root : shoot ratio (root dry weight/fruit dry weight). Plants were grown in a mixture of 3 perlite : 1 vermiculite in the greenhouse and lathhouse.

| Treatment          | Length (m/plant) | Dry wt (g/plant) | N concn (g·kg⁻¹) | N uptake (mg/plant) | Root : shoot ratio |
|--------------------|------------------|------------------|------------------|---------------------|-------------------|
|                    |                  |                  |                  |                     |                   |
| Residue            |                  |                  |                  |                     |                   |
| +                  | 350 a            | 2.7 a            | 12.7 a           | 34 a                | 0.07 a            |
| –                  | 317 a            | 2.3 a            | 12.8 a           | 28 a                | 0.08 a            |
| N fertilization (g/plant) |      |                  |                  |                     |                   |
| 0                  | 248 b            | 1.9 b            | 14.0 a           | 26 a                | 0.09 a            |
| 4.1                | 365 a            | 2.6 a            | 11.8 a           | 30 a                | 0.07 a            |
| 8.2                | 389 a            | 3.0 a            | 12.5 a           | 37 a                | 0.07 a            |
| Interaction        | NS               | NS               | NS               | NS                  | NS               |
| Lathhouse          |                  |                  |                  |                     |                   |
| Residue            |                  |                  |                  |                     |                   |
| +                  | 157 a            | 5.8 a            | 15.9 a           | 92 a                | 0.23 b            |
| –                  | 135 b            | 4.1 b            | 16.2 a           | 67 b                | 0.38 a            |
| N fertilization (g/plant) |      |                  |                  |                     |                   |
| 0                  | 124 b            | 3.9 b            | 16.2 a           | 61 b                | 0.38 a            |
| 4.1                | 156 a            | 4.9 b            | 15.3 a           | 74 ab               | 0.29 ab           |
| 8.2                | 158 a            | 6.2 a            | 16.7 a           | 104 a               | 0.24 b            |
| Interaction        | NS               | NS               | NS               | NS                  | NS               |

*Mean separation within columns and sets by the least square means test, P ≤ 0.05.
**Nonsignificant.

Real-time analysis of data...
Table 4. The effects of hairy vetch residue and N fertilization on NH$_4^+$, NO$_3^-$, and inorganic N concentrations in the 3 perlite : 1 vermiculite mixture at tomato transplanting and harvest.

| Treatment | Transplanting | Harvest |
|-----------|---------------|---------|
|           | NH$_4^+$ (mg/kg) | NO$_3^-$ (mg/kg) | Inorganic N (mg/kg) |
|           | NH$_4^+$ (mg/kg) | NO$_3^-$ (mg/kg) | Inorganic N (mg/kg) |
| Residue   |               |               |                    |
| +         | 19.1 a        | 17.0 a        | 36.1 a             |
| –         | 11.3 b        | 15.6 a        | 26.9 b             |
| N fertilization (g/plant) |               |               |                    |
| 0         | 16.4 a        | 15.6 a        | 32.0 a             |
| 4.1       | 16.1 a        | 16.7 a        | 32.8 a             |
| 8.2       | 13.1 a        | 16.7 a        | 29.8 a             |
| Interaction |                |               |                    |
| NS        | NS            | NS            | NS                 |

Mean separation within columns and sets by the least square means test, $P \leq 0.05$.

Table 5. Regression analysis of tomato fruit yield, stem, leaf, root, and total (fruits + stems + leaves + roots) dry weight and N uptake with N fertilization, and determination of N fertilizer equivalence (NFE) for hairy vetch residue in the greenhouse and lathhouse (n = 18).

| Parameter | Greenhouse | Lathhouse |
|-----------|------------|-----------|
|           | a          | b         | R$^2$   | NFE |
|           | a          | b         | R$^2$   | NFE |
| Fruit no. | 6.1        | 0.75      | 0.50    | 5.1 |
| Fruit fresh yield | 506.0       | 82.0      | 0.87    | 4.4 |
| Fruit dry yield | 38.3        | 5.6       | 0.83    | 4.4 |
| Fruit N uptake | 505.0       | 63.0      | 0.77    | 5.0 |
| Stem dry wt. | 22.0        | 2.9       | 0.68    | 5.2 |
| Stem N uptake | 145.0       | 18.0      | 0.61    | 5.6 |
| Leaf dry wt. | 17.3        | 2.8       | 0.74    | 5.5 |
| Leaf N uptake | 188.0       | 37.0      | 0.70    | 5.5 |
| Root length density | 261.0       | 17.0      | 0.35    | 5.2 |
| Root dry wt. | 1.9         | 0.13      | 0.47    | 6.2 |
| Root N uptake | 26.0        | 1.4       | 0.26    | 5.7 |
| Total dry wt. | 79.0        | 11.4      | 0.87    | 5.0 |
| Total N uptake | 864.0       | 118.0     | 0.79    | 5.3 |

$R^2$ values $\leq 0.29$ are significant at $P \leq 0.05$.

to 7.9 g/plant N fertilization. As a result, tomato yield and N uptake per unit amount of N supplied was greater with HVR than with N fertilization. Therefore, this residue can be successfully used as N fertilizer for tomato production.

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