Morphological Plasticity in Watermelon in Response to Interspecific Competition in a Low-Resource Intercropping System

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Introduction

•Intercropping with functionally diverse species is a way of mimicking nature, creating an architecturally complex and dense multi-layered canopy

•Plants that form part of a more dense canopy undergo intense competition for light and respond by changing leaf morphology and altering resource allocation patterns

•Specific leaf area (SLA), leaf area per unit dry mass, maximizes light interception by increasing relative growth rate, leaf N content, and, thus, optimizing photosynthetic capacity per unit leaf area

•There is a strong relationship between SLA and leaf N, and SLA and photosynthetic N-use efficiency (PNUE; photosynthetic capacity per unit leaf N) as PNUE is associated with higher relative growth rate, thereby increasing plant fitness and the ability to compete with neighbors

Objective

•***To evaluate leaf-level acclimation and photosynthetic nitrogen-use efficiency in watermelon in a functionally diverse intercropping system***

Hypothesis

We hypothesized that as light competition intensity increased, watermelon would respond by increasing SLA, leaf N concentration, and PNUE

Methods

•Two-year field study using 5 crop species (Table 1) and 3 replicates (field site and plot layout information can be found in Franco *et al.*, 2015)

•In 2011, peanut was direct seeded on August 1st followed by watermelon on August 7th, okra and cowpea on August 14th and 15th and 3-inch tall pepper transplants on August 18th (plants spaced 30.5 cm apart)

•Due to over-competition by watermelon in year 1, planting dates were altered and plants were direct seeded earlier in the season in year 2 (Peanut and okra on June 21st and 22nd, cowpea on June 27th, pepper transplants on July 3rd and watermelon on July 12th)

•Five controls of each species in monocrop were used. Six treatments used were:

within-row intercropping systems consisting of

- **peanut and watermelon (W_{pw})**
- **peanut, watermelon, and okra (W_{pwo})**
- **peanut, watermelon, okra, and cowpea (W_{pwoc})**
- **peanut, watermelon, okra, cowpea, and pepper (W_{all})**

and a strip intercropping system consisting of

- **peanut and watermelon in alternating single rows (S_{pw})**

•Gas-exchange was measured on the youngest fully expanded watermelon leaf between 1200 and 1400 at full canopy (69 and 84 days after planting in year 1 and year 2, respectively)

•Leaves were collected and scanned with a flatbed scanner to derive total leaf area, oven dried at 24°C for 48 hours, ground, and analyzed for C and N content

•SLA was calculated as the ratio of leaf area (m^2) to leaf dry mass (kg)

•PNUE was calculated as photosynthetic rate per unit leaf area (µmol CO_2 s^{-1} cm^{-2}) / gram of N per unit leaf area (g N * SLA) to give µmol CO_2 [mol N]$^{-1}$ s^{-1}

•Data were analyzed using ANOVA and regression analyses in JMP 10.0.2 software

Table 1. Component crop characteristics

Crop	Variety	Family	Function	Architecture
Peanut	Tamspan 90	Fabaceae	nitrogen fixation, smother crop	low/ mid growth form
Watermelon	*TAMU mini	Cucurbitaceae	smother crop, shading	low growth form
Okra	Clemson spineless	Malvaceae	pollinator attractant, structural support	tall growth form
Cowpea	Texas pinkeye	Fabaceae	nitrogen fixation, pollinator attractant	mid growth form
Pepper	Jalapeño/Serrano	Solanaceae	pest barrier	mid growth form

*Unreleased variety

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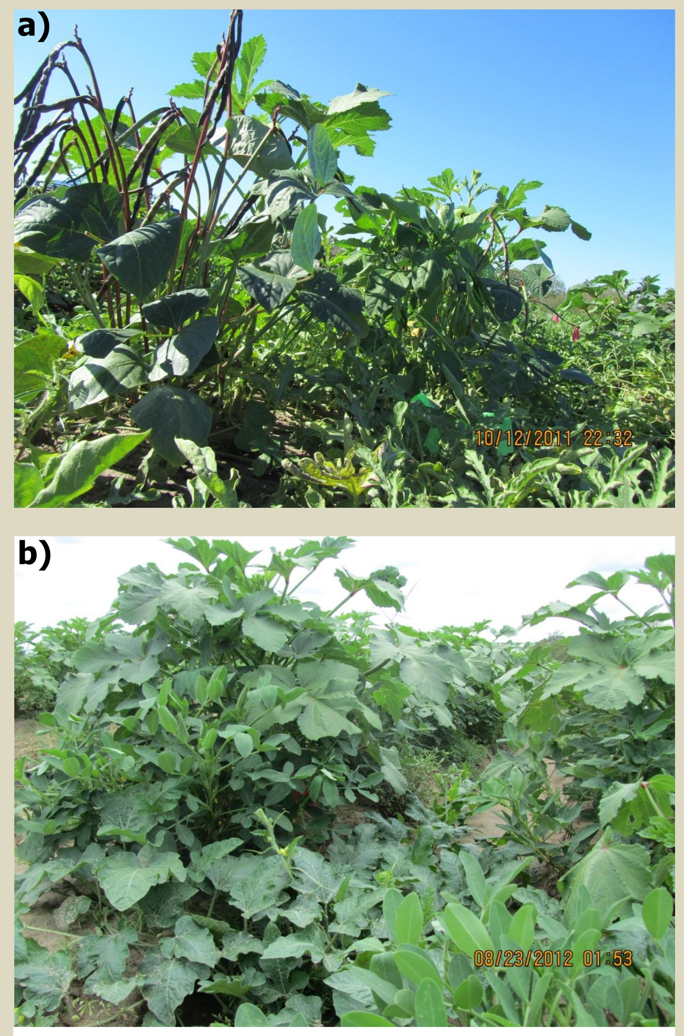

Fig 1. Intercropped peanut, watermelon, okra, cowpea and pepper highlighting the variable growth form of component crops in an architecturally complex system in year 1 (a) and year 2 (b).

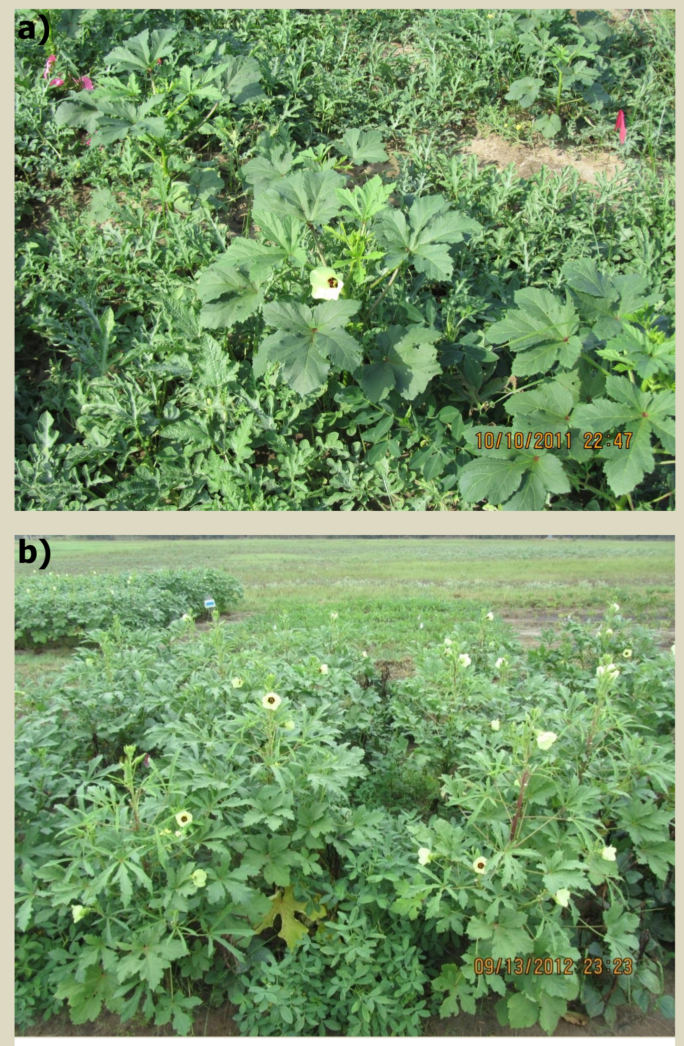

Fig 2. Intercropping mixture of peanut-watermelon-okra-cowpea (W_{pwoc}) in year 1 (a) and year 2 (b). Watermelon canopy dominated all intercropping treatments in year 1, whereas an okra-dominated canopy was evident in year 2.

Results

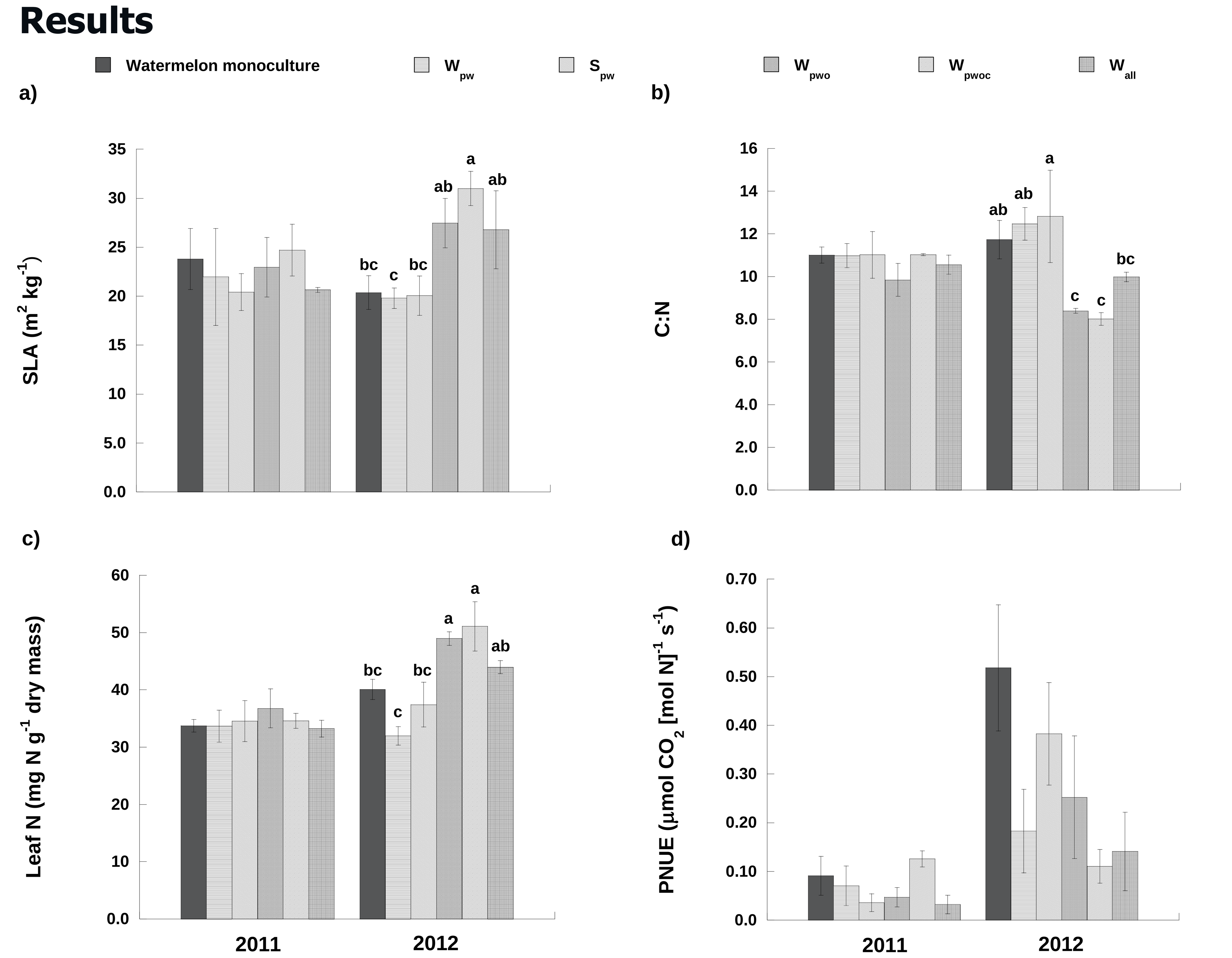

Fig 3. Watermelon (a) specific leaf area (SLA; m^2 kg^{-1}), (b) leaf carbon to nitrogen ratio (C:N), (c) leaf nitrogen concentration based on leaf dry mass (Leaf N; mg N g^{-1}), and (d) photosynthetic nitrogen-use efficiency (PNUE; µmol CO_2 [mol N]$^{-1}$ s^{-1}). Different letters indicate statistically significant differences ($P \leq 0.05$) between means within years according to Tukey's LSD test.

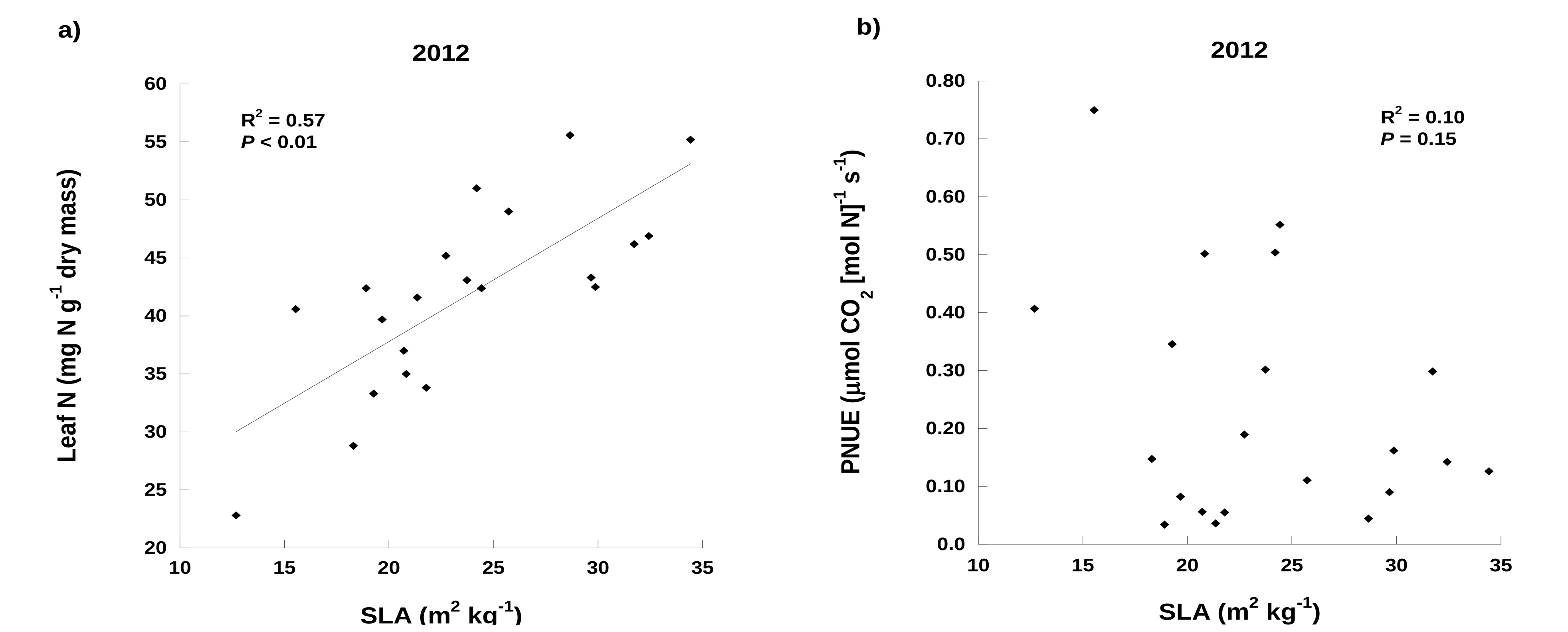

Fig 4. Relationship between watermelon (a) specific leaf area (SLA; m^2 kg^{-1}) and leaf nitrogen concentration (Leaf N; mg N g^{-1}), and between (b) SLA and photosynthetic nitrogen-use efficiency (PNUE; µmol CO_2 [mol N]$^{-1}$ s^{-1}) in 2012.

Summary

- In year 1, watermelon was dominant and did not undergo intense competition for light as seen visually in Fig. 2a and supported by the data (Fig's. 3a, b, c)
- In year 2 when light competition was greatest due to okra dominance (Fig. 2b), watermelon acclimated by increasing SLA (e.g. larger but thinner leaves) and investing more N for rapid growth (higher leaf N concentration, lower C:N) in treatments containing okra (Fig's. 3a, b, c)
- No differences were found in watermelon PNUE between monocrop and intercropping treatments as was hypothesized (Fig. 3d)
- SLA was positively linearly correlated with leaf N concentration (Fig. 4a); however, no relationship was found between SLA and PNUE (Fig. 4b)
- **Changes in PNUE within a species may be too small to detect and may be more pronounced when comparing species with different life strategies**
- **Morphological plasticity demonstrated by watermelon in year 2 may play an important role in optimizing net CO_2 assimilation rates over the entire leaf, thus maximizing canopy-level photosynthesis and enhancing competitive ability**
- **Enhancing competitive ability may, however, come at a yield cost as energy is re-allocated from fruit production to growth as was evident in lower watermelon yields in year 2 (Franco *et al.*, 2015)**
- **With increasing interest in multifunctional intercrop and cover crop mixtures, these findings may inform selection of species and relative planting dates given how interspecific species interactions may alter leaf N allocation and C:N ratios and, subsequently, above-ground nutrient inputs**

Literature Cited

Franco, J.G., King, S.R., Masabni, J.G., Volder, A. 2015. Plant functional diversity improves short-term yields in a low-input intercropping system. AgrEcosystEnviron 203, 1-10.