Genotypic variation in NUE among carinata genotypes in a controlled environment

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Rationale

- *Brassica carinata* is a non-food oilseed crop that has received attention for its potential as a low-input biofuel feedstock suitable for production in the southeastern United States (SE US) during the winter months.
- However, most soils of the SE US are not naturally as productive as soils found in other regions of the US because they are highly weathered, acidic, and with less than 1% organic matter content.
- To increase crop yield in these soils, N fertilizer is applied, often at rates greater than the rate the crop can consume, resulting in a surplus of N in the soil that leads to environmental problems.
- The sandy nature of these soils further compounds the problem because it makes them easily prone to soil erosion.
- Given the potential significance of carinata as a bioenergy crop, and the potential environmental implications of N mismanagement over a large production acreage, there is clearly a need to develop carinata cultivars with improved N stress tolerance and high seed yield under low soil N.

Research questions and hypothesis

- Can carinata produce optimal yield under low N rates?
- How do carinata genotypes vary with respect to N-use efficiency (NUE) and its components?
- What is the relative importance of N-uptake efficiency and N-utilization efficiency to NUE?

Understanding these issues could facilitate the Identification of carinata genotypes with superior NUE and served as the goal of this research.

- 1st H_o: Carinata genotypes vary with respect to NUE and its components.
- 2nd H_o: N-uptake and N-utilization efficiencies are important determinants of NUE in carinata.

Objectives

- Quantify genotypic variation in NUE and its components (N-uptake efficiency, NupE; and N-utilization efficiency, NutE) among carinata genotypes under contrasting N supplies.
- Establish the relative importance of N-uptake efficiency and N-utilization efficiency to NUE.

Materials and Methods

Study Details

Research location:

- Greenhouse facility, North Florida Research and Education Center, Quincy, FL (30.54, -84.59).

Years:

- 2019-20: Completed.
- 2021-22: Planned.

Management:

- Followed procedure previously described by Seepaul *et al*. (2016).

Experimental Design and Setup

Randomized complete block design:

- Two-way factorial arrangement.
- Total of 576 experimental pots.
- Three N rates (0, 80.5, 161 mg N L^{-1} in Hoagland solution).
- 16 carinata genotypes.

Measurements and Data Analysis

Response variables:

- Carinata biomass, biomass N, seed yield.

Estimations:

- $NUE = \frac{SYF - SYC}{NR}$; $NupE = \frac{NCF - NCC}{NR}$; $NutE = \frac{SYF - SYC}{NCF - NCC}$
- SYF and SYC: the seed yield (g $plant^{-1}$) in fertilized and control pots respectively; NR: the N rate (g pot^{-1}); NCF and NCC: total plant N content (g $plant^{-1}$) in fertilized and control pots, respectively.

Statistical analyses:

- ANOVA using SAS 9.4: PROC GLIMMIX.
- Fixed effects were N rate, genotype, and their interaction. Random effect was rep.
- Correlation using SAS 9.4: PROC CORR.
- Level of significance at $P < 0.05$.

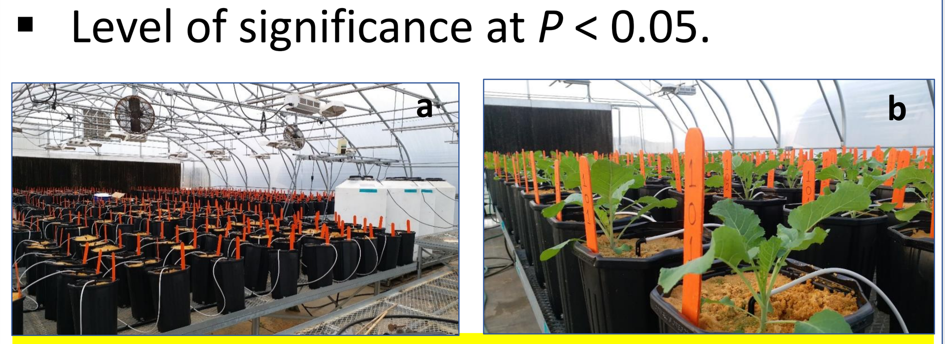

Figure 1. Set-up of the NUE experiment (**a.** before carinata emergence; and **b.** after carinata emergence) in the greenhouse.

Results

Genotypic variation: Yield, NUE and its components

Table 1. Analysis of variance for yield, NUE and its components at each of the three N levels and for combined N levels in 16 carinata genotypes.

N level	Source of variation	Yield	N-use efficiency	N-uptake efficiency	N-utilization efficiency
		Pr > F			
No-N	G	0.0019	-	-	-
Low-N	G	0.0017	0.0017	0.5238	0.0066
High-N	G	0.0003	0.0003	0.4764	0.0031
Combined N levels analysis	N	<0.0001	<0.0001	0.0207	<0.0001
	G	<0.0001	<0.0001	0.5364	<0.0001
	N × G	0.0001	0.0176	0.6392	0.0570

Abbreviations: G, Genotype; N, N levels.

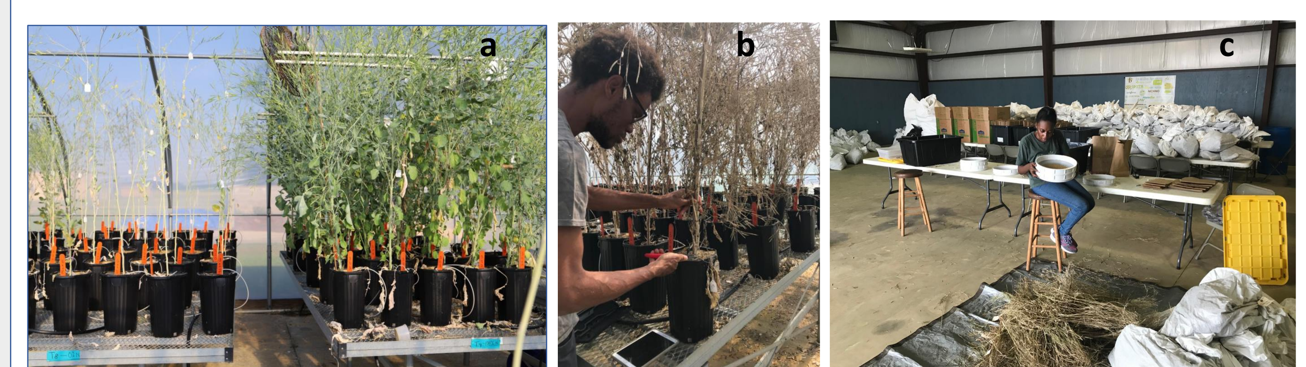

Figure 2. a. Carinata at full pod development stage (no-N on the left, high-N on the right) **b.** Harvesting carinata at physiological maturity **c.** Hand threshing carinata.

- The genotypes varied with respect to seed yield and NUE at no-N, low-N, high-N, and at combined N levels. The variation may be attributed to the differences observed among the genotypes for N-utilization efficiency (Table 1).
- No significant differences for N-uptake efficiency were observed among the genotypes at all N levels (Table 1).
- Genotype interaction with nitrogen had influence on yield and NUE, indicating difference in rank-order of the genotypes under different nitrogen levels (Table 1).

Nitrogen use efficiency

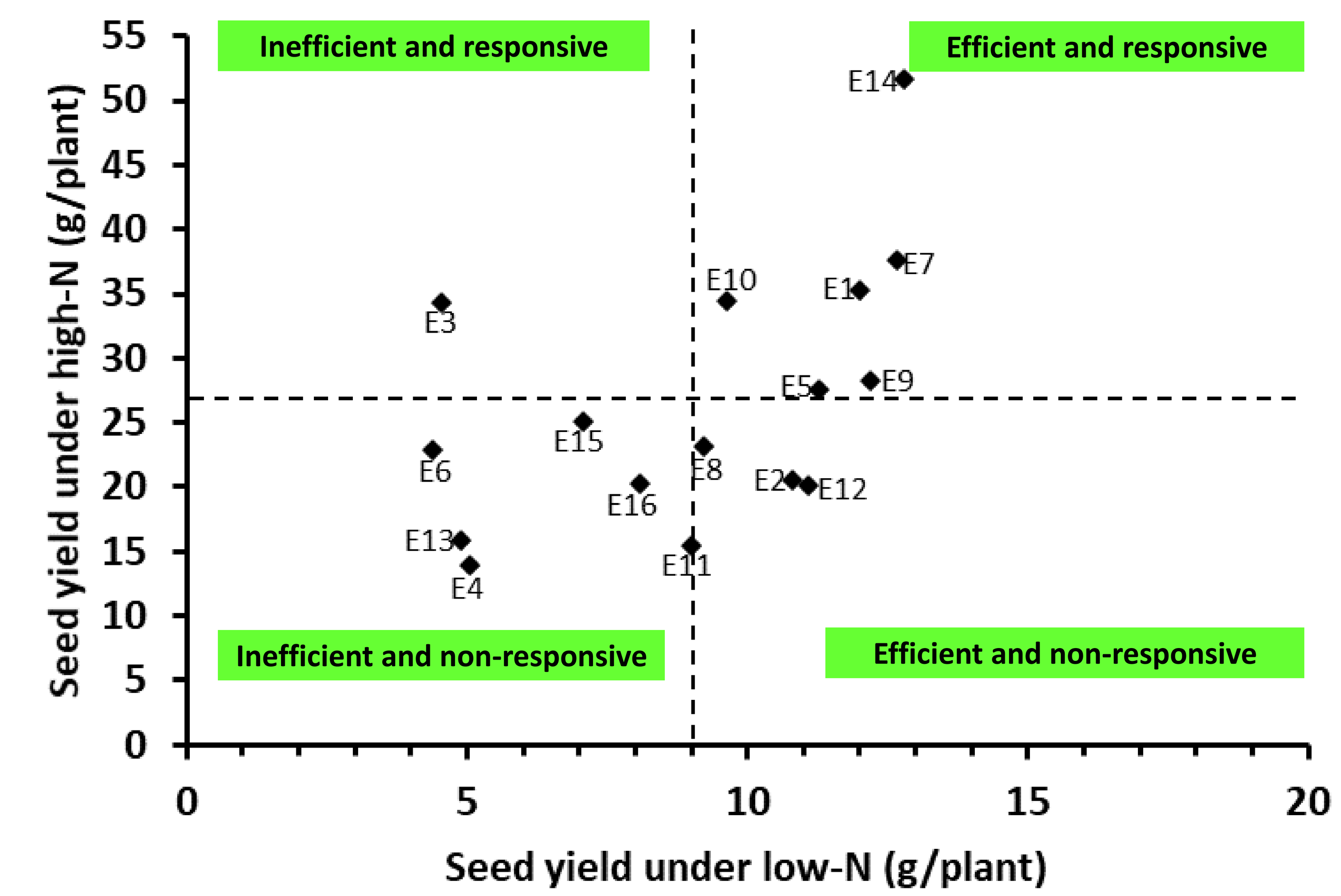

Figure 3. Biplot for seed yield in 16 carinata genotypes at high and low levels of N in Hoagland solution. Broken lines represent mean seed yields.

- Six genotypes were found to be N-use efficient and responsive, and this included entry 5 (Avanza-641), which was the variety used as check for the study (Figure 3).
- Entry 14 (AGR605-1EB1) produced the highest seed yield under both low- and high-N and was the most N-use efficient and responsive genotype (Figure 3).
- Entry 4 (DH-157.715) and 13 (AGR044-3B2) were the lowest yielding under both low- and high-N, making them the most inefficient and most non-responsive genotypes (Figure 3).

Importance of N-uptake efficiency and N-utilization efficiency to NUE

Table 2. Correlation coefficients among NUE and its components for 16 carinata genotypes grown at low (below the diagonal) and high (above the diagonal) levels of N in Hoagland solution.

	N-use efficiency	N-uptake efficiency	N-utilization efficiency
N-use efficiency		-0.02^{ns}	0.95^{****}
N-uptake efficiency	0.31^{*}		-0.31^{*}
N-utilization efficiency	0.90^{****}	-0.11^{ns}	

Abbreviations: ns, not significant; *,****, significant at $P < 0.05$ and $P < 0.0001$, respectively.

- It is likely that carinata may have employed N-utilization efficiency as a mechanism to achieve N-use efficiency.
- This conjecture was supported by the significant positive correlation between N-use efficiency and N-utilization efficiency under both low- and high N levels in Hoagland solution (Table 2).
- N-uptake efficiency and N-utilization efficiency were negatively correlated at both N levels in Hoagland solution, showing significance only at high-N (Table 2). This may not allow the simultaneous improvement of carinata genotypes for both traits.

Conclusions

- Genetic variation for N-use efficiency and N-utilization efficiency exists among the carinata genotypes studied.
- N-utilization efficiency contributed to high seed yield under low- and high-N levels, making it more important than N-uptake efficiency for achieving NUE under low-N.

Future Research

- This study will be repeated for an additional year during 2021-22 carinata growing season.
- Gene expression analysis to study NUE-related target genes on some of the identified nitrogen use efficient genotypes will be conducted upon the completion of the greenhouse study.

References

- Seepaul R., George S., Wright, D.L., 2016. Comparative response of *Brassica carinata* and *Brassica napus* vegetative growth, development and photosynthesis to nitrogen nutrition. Ind. Crops Prod. 94, 872-883.

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