Nitrogen use efficiency among genetically diverse set of carinata genotypes

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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 what 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 (leaching and run-off).
- 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?
- 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:

- $\mathrm{NUE} = \frac{SYF - SYC}{NR}$; $\mathrm{NupE} = \frac{NCF - NCC}{NR}$; $\mathrm{NutE} = \frac{SYF - SYC}{NCF - NCC}$
- 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 $p < 0.05$.

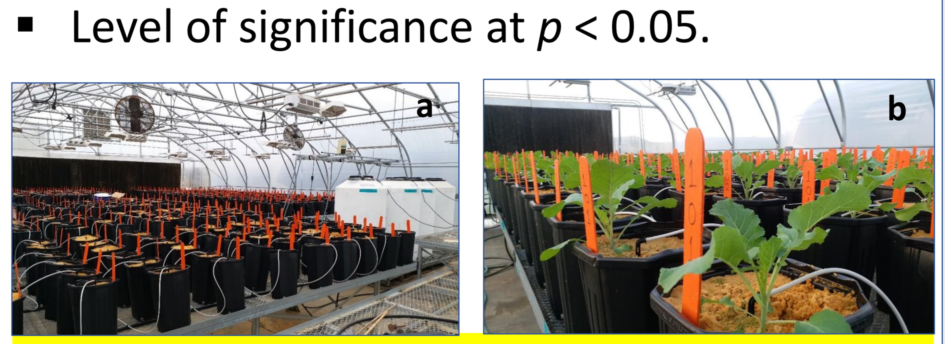

Figure 1. Set-up of the NUE experiment (**a.** before carinata emergence; and **b.** after carinata emergence) in the greenhouse.

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.

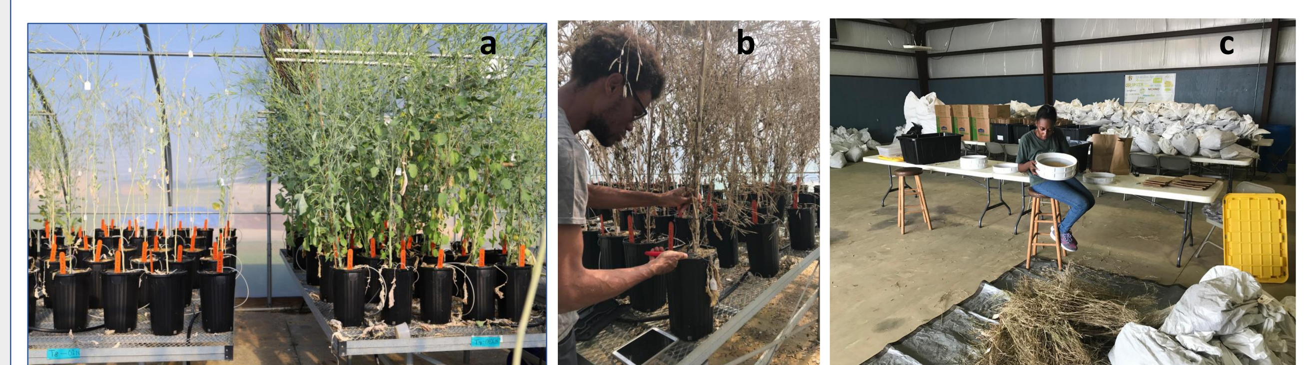

Figure 2. a. Carinata at full pod development stage (no-N on the left, high-N on the right) **b.** Harvesting carinata at physiological maturity **c.** Hand threshing carinata.

- 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

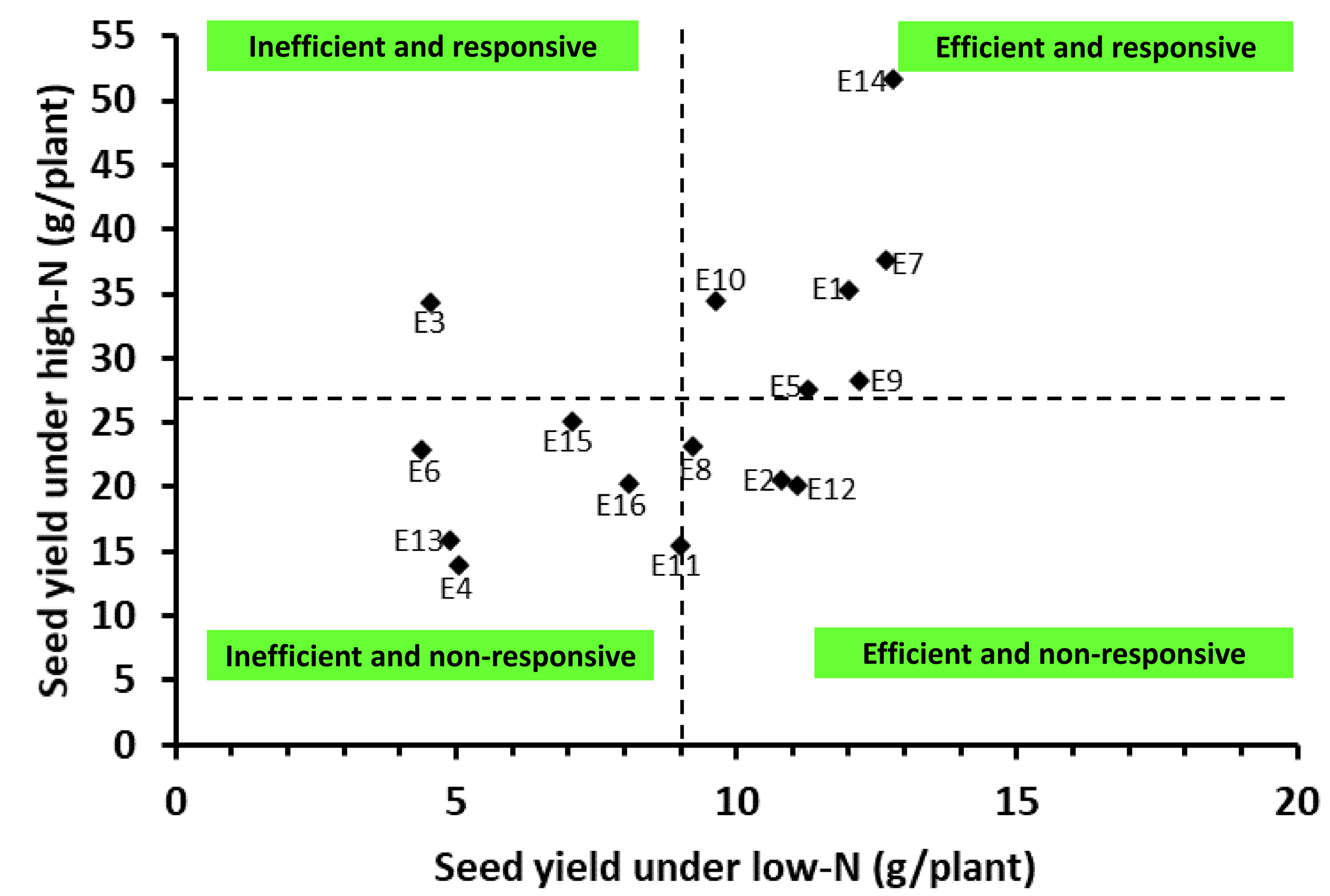

Figure 3. Biplot for seed yield in 16 carinata genotypes at high and low levels of N in Hoagland solution. Broken lines represent mean seed yields.

- 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.

Acknowledgements: This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2016-11231. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. This work is/was supported by the USDA National Institute of Food and Agriculture, Hatch project 1007448.