Uptake efficiency and partitioning of soil and fertilizer N sources by canola, wheat, and pea

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Introduction

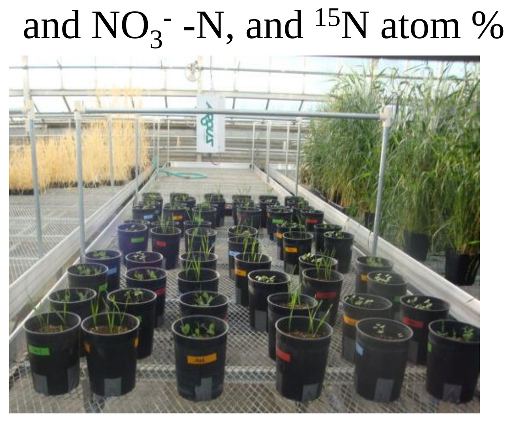
- Nitrogen use efficiency (NUE) is a major concern due to the negative environmental and economic consequences of N surpluses.
- Globally, 30- 50% of fertilizer N is recovered in grain (Smil, 1999; Raun and Johnson, 1999, Conant, 2013)
- Approximately 29% of fertilizer N is retained in soil and more than 60% of plant N is derived from soil N sources (Gardner and Drinkwater, 2009)
- Despite its contribution, soil N is often not factored into NUE equations.

Objectives of the greenhouse study:

(1) To identify differences in plant productivity and N partitioning among crop species in response to ^{15}N fertilization
(2) To determine if increasing N fertilization causes a decrease in the relative contribution of soil-derived N to cereal, oilseed, and legume N uptake
(3) To assess whether N uptake efficiencies based on total N supply exceed fertilizer N recovery estimates due to the contribution of soil-derived N.

Materials and Methods

- Wheat (*Triticum aestivum* L. cv. Louise), inoculated pea (*Pisum sativum* L. cv Aragorn), and canola (*Brassica napus* L. cv. Dekalb 55-55) received 6, 60, 180 and 420 mg N kg^{-1} with 5 replicates
- Three plants were grown in each 1 kg pot of 50% soil (Palouse fine-silty, mixed, superactive, mesic pachic ultic haploxeroll) and 50% potting soil: 20 mg inorganic N kg^{-1}, 0.28% TN, 5% TC, pH 5.5, E.C. 2.4 mmhos cm^{-1}, 86 mg P kg^{-1}, 935 mg K kg^{-1}, and 22.3 $cmol_c$ kg^{-1} total bases
- Fertilizer was split in three applications (16, 32, and 47 days after planting)
- Pea plants were harvested at 67 days after planting, while canola and wheat were harvested at 92 days after planting.
- Samples were partitioned into grain, residue, root, and soil components in addition to collected canola leaves.
- Soil and plants were analyzed for total C and total N, NH_4^+-N and NO_3^- -N, and ^{15}N atom % excess




Calculations:
(1) Percent N derived from fertilizer = %Ndff = (^{15}N atom % plant – 0.3680)/(^{15}N atom % excess in fertilizer)*100
(2) Percent N derived from the atmosphere = %Ndfa = (1 – [^{15}N atom % excess in pea/ ^{15}N atom % excess in wheat]*100
(3) Percent N derived from soil = %Ndfs% = 100- %Ndff - %Ndfa
(4) ^{15}N Uptake efficiency = $^{15}NUpE$ % = (QNdff recovered in roots, residue, and/or grain)/ (Applied fertilizer N) *100
(5) N uptake efficiency = NUpE = Total N uptake (roots, residue, and/or grain) / (preplant inorganic N + fertilizer applied + apparent N mineralization + N derived from the atmosphere)
(6) Apparent N mineralization = {(Total N uptake [roots, residue, and/or grain]$_{control}$ + inorganic N at harvest $_{control}$) – (preplant inorganic N $_{control}$ + trace fertilizer application)}/0.90 to assume a 10% loss
(7) Apparent fertilizer N recovery % (ANR) = (total N uptake [roots, residue, and/or grain] fertilized – total N uptake [roots, residue, and/or grain] control) / N rate *100
(8) Soil-derived N recovery % = Soil-derived N uptake / Apparent N mineralization* 100

Statistics: Two-way ANOVA for effects of N rate and crop species (SAS). Mean separation by the Tukey's HSD test ($p<0.05$)..

Results

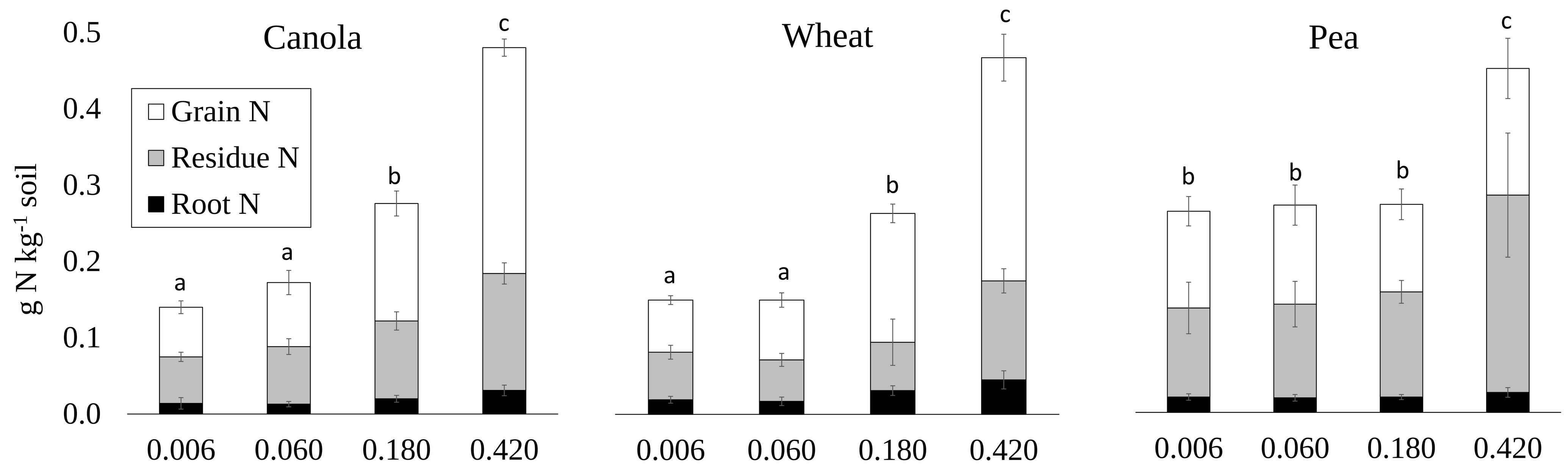


Figure 1. N partitioning in canola, wheat, and pea as a function of N fertilization rate. Canola and wheat exhibited similar N partitioning patterns in response to fertilizer. Pea was less responsive to N additions. (Error bars = standard deviation)

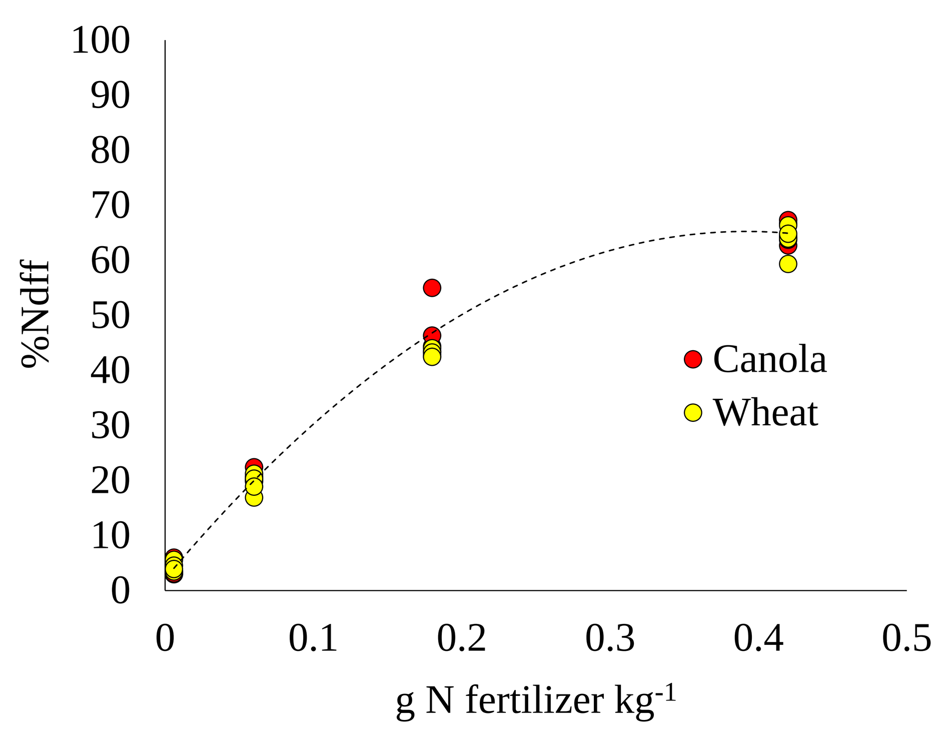


Figure 2. Percent N derived from fertilizer in canola and wheat plants increased non-linearly with N rate. The %Ndff reached a maximum at the highest N rate.

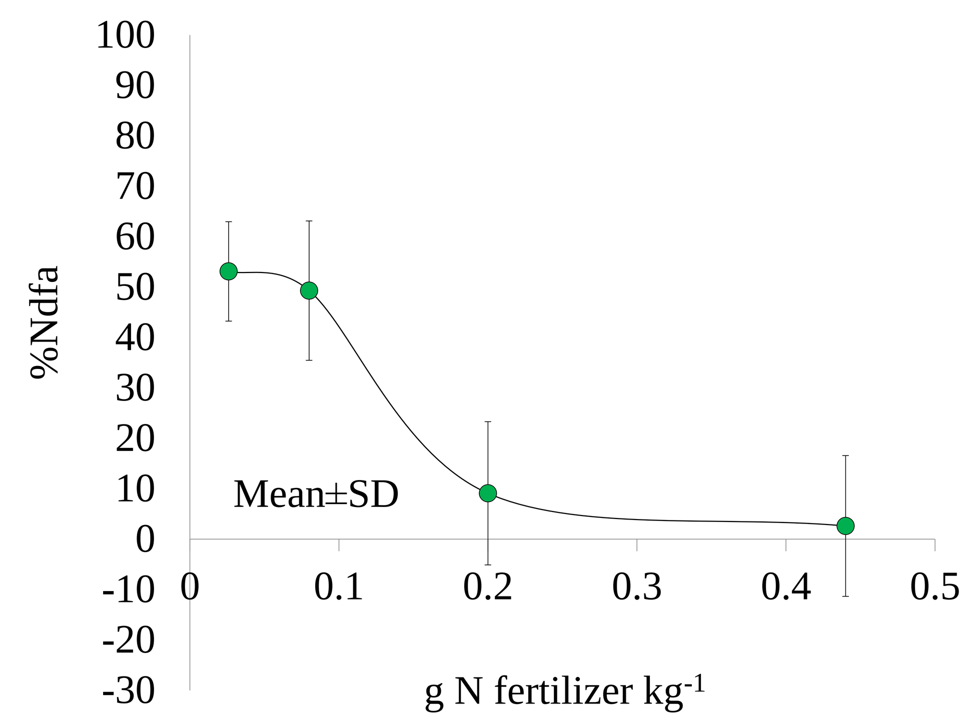


Figure 3. Percent N derived from the atmosphere in pea plants decreased non-linearly with N rate. Almost no N was derived from N fixation at the highest N rate.

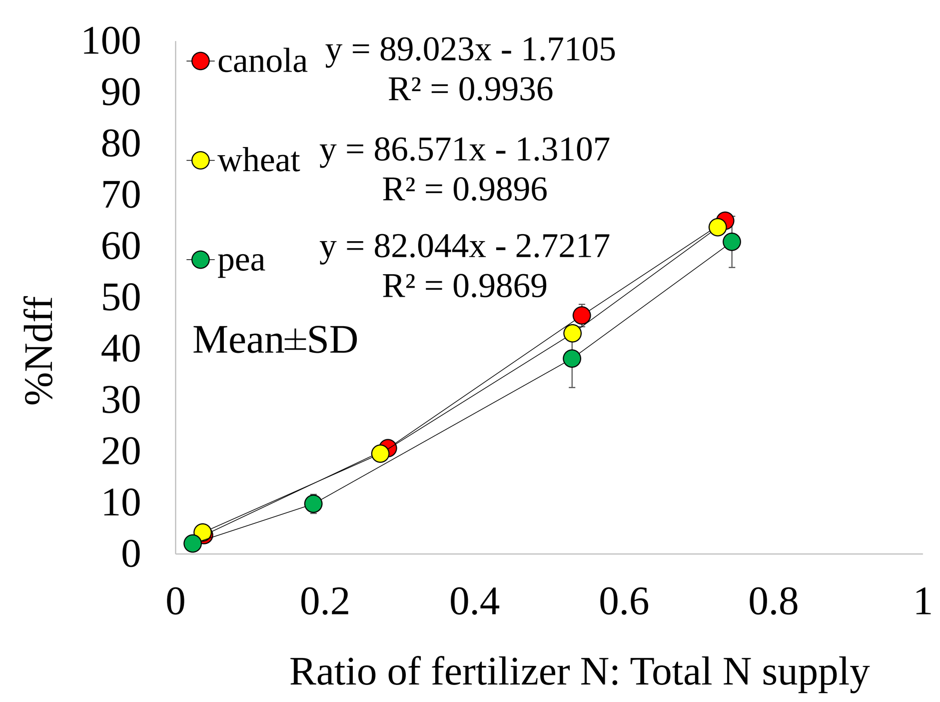


Figure 4. Percent N derived from fertilizer in canola, wheat, and pea as a function of the predominance of N fertilizer in the total N supply. %Ndff increased linearly as fertilizer N made up a greater proportion of the N supply.

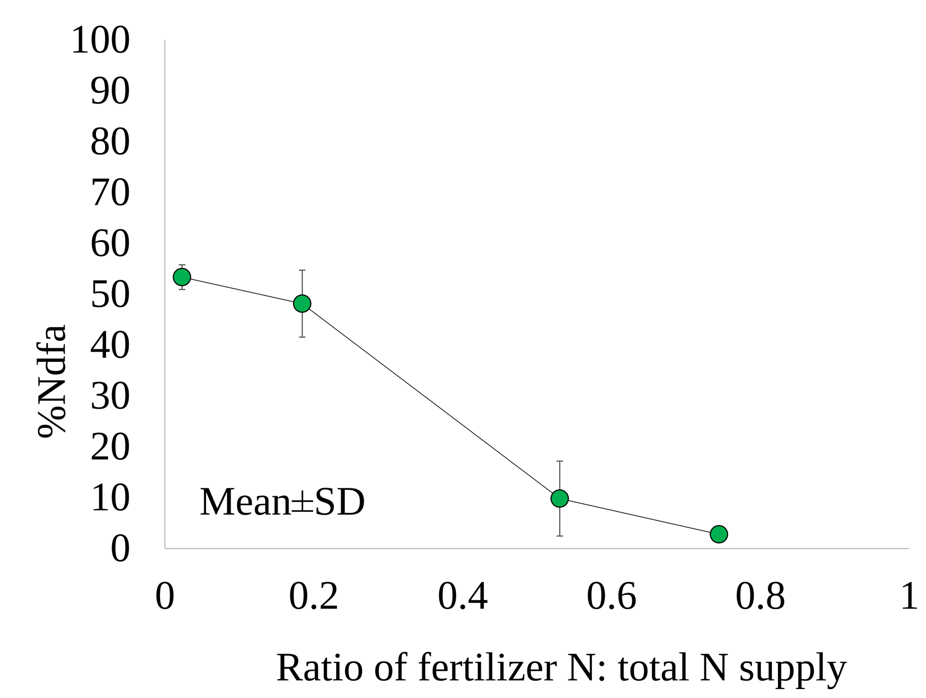


Figure 5. Percent N derived from the atmosphere by pea as a function of the predominance of N fertilizer in the total N supply. %Ndfa deceased as fertilizer N made up a greater proportion of the N supply.

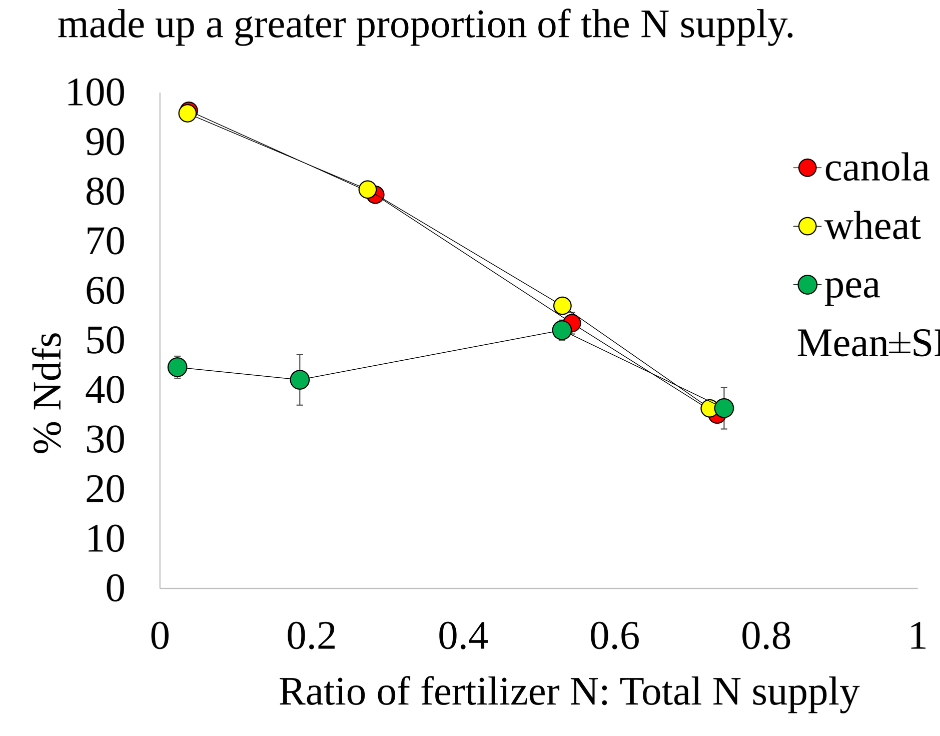


Figure 6. Percent N derived from soil as a function of the predominance of N fertilizer in the total N supply. %Ndfs deceased as fertilizer N made up a greater proportion of the N supply for canola and wheat, but not for pea.

Table 1. Effect of N rate on soil N recovery and ^{15}N retention

N rate	Soil-derived N recovery	^{15}N Recovery in soil
mg kg^{-1}	% (Mean±SD)	
	Canola	
0.006	89.4±3.5	
0.060	90.7±5.7	64.1±20.4
0.180	97.5±5.5	52.4±10.4
0.420	111.4±3.4	34.2±4.0
	Wheat	
0.006	89.8±1.4	
0.06	75.3±5.4	88.9±17.2
0.18	93.9±5.6	37.7±9.5
0.42	106.2±5.1	24.6±2.4
	Pea	
0.006	105.9±16.3	
0.06	89.7±11.6	79.2±10.2
0.18	107.6±5.4	47.5±15.8
0.42	125.4±17.9	42.7±12.1

Results, continued

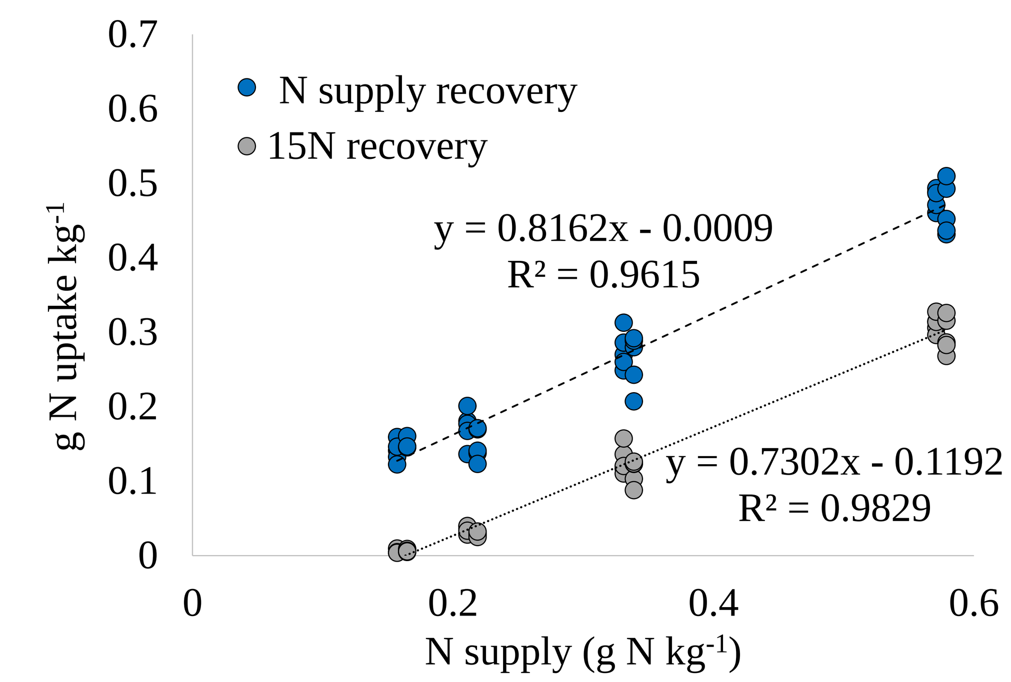


Figure 7. Effect of increasing fertilization on total N and ^{15}N uptake by canola and wheat plants. Plants recovered a greater proportion of total N than ^{15}N fertilizer.

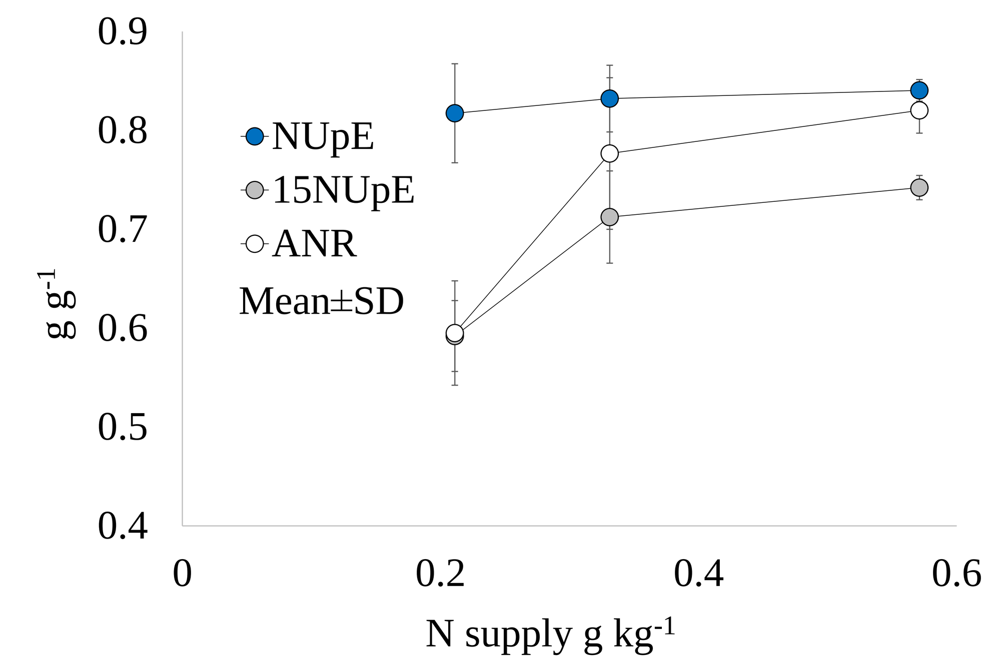


Figure 8. Effect of N rate on NUpE, $^{15}NUpE$, and ANR. $^{15}NUpE$ were less than NUpE of the total N supply. ANR increased with fertilization .

Discussion

- Canola and wheat had similar N uptake and partitioning patterns. Canola's relatively lower NUE than wheat (Gan et al., 2010; Hocking et al., 2002) was not due to a lesser N uptake efficiency. N uptake by pea was buffered by N fixation at low N levels.
- Soil N and fertilizer N were not taken up in equal proportions. Only 40% of the plant N was derived from fertilizer N even when fertilizer made up 50% of the N supply.
- The percentage of N derived from fixation decreased from 53 to 0% in response to N additions. Large reductions occurred between 60 and 180 mg kg^{-1} of fertilizer added, unlike the linear decrease previously reported (Voisin et al.,2002).
- N mineralization increased upon fertilization since soil N uptake exceeded apparent N mineralization at the highest fertilization rate.
- Apparent N losses were low (7 to 17%), and significant amounts of N were immobilized by soil.
- **Conclusion**: Our findings highlight the contribution of non-fertilizer N sources to plant nutrition. Despite low N losses and high fertilizer retention, plants took up proportionately less fertilizer N. Therefore, we recommend that total N supply is factored into NUE and fertilizer N recommendations.

Acknowledgments

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