Responses of contrasting oat genotypes to abiotic stresses

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Outline

• General introduction of abiotic stresses
• Terminologies for assessing tolerance of crop plants to abiotic stresses
• Examples of characterizing tolerance of oat genotypes to N stress
• Concluding remarks
Introduction

- Abiotic stress: Adverse environmental conditions that threaten plant growth and development; one of the major threats to agriculture
- Drought, salinity and nutrient limitation concurrently occur during crop growth in many parts of the world
- It is estimated that N deficiency, drought and salinity cause extensive losses to agricultural production
- The greatest concern and largely unknown are the interaction of among different types of stresses will have on many crops including oats.
Oat is recognized as an important cereal food crop. 
Grain yield of hulless oat is < that of hulled oats. 
Oat is well adapted to nutrient-poor soils, low rainfall and moderate soil salinity levels. 
Hulless oat has excellent grain quality, attractive to producers and industry, for specialized markets. 
There has been little improvement in oat yield and nutrient management as lodging occurs with increasing N supply. 
N nutrition is an important determinant for crop growth, yield and food quality. 
Timing and rate of application are the two major factors affecting N uptake, partitioning, remobilization and use efficiency.
Terminologies

• **NUE**: Plant N uptake as a ratio of applied fertilizer N. Two methods:
  – Difference method: \( \frac{\text{plant TN}_f - \text{plant TN}_u}{\text{fertilizer N}} \)
  – \( ^{15}\text{N} \) labeling approach: ratio of plant \( ^{15}\text{N} \) a.e. to fertilizer N a.e.

• **aNUE** \( (A_{EN}) \): kg grain yield increase \( G_w \)/kg N applied \( N_s \)

  – N uptake efficiency: Plant N \( N_t \)/Ns
  – N utilization efficiency: \( G_w / N_t \)

• **pNUE**: The ratio of net photosynthetic rate to leaf N content

• **N Fertilizer replacement value (NFRV)**: N fertilizer that should be applied on unmanured or monocultured lands to obtain the yield

• **Cost/value ratio**: cost of 1 kg fertilizer N/price of 1 kg yield, e.g. $1/kg N and $0.2/kg corn, Cvr = 1/0.2 = 5

• **Economically optimum N rate or most economic rate of N (EORN)**: minimum of fertilizer N needed for max economic yield (Neeteson and Wadman, 1987. Fert. Res. 12: 37-52)
**N nutrition index**

- N nutrition index (NNI), proposed as a plant-based approach for assessing crop N nutrition:
  \[\text{NNI} = \frac{\text{Actual}[N]}{N_c}\]
  Where, \(N_c\) is minimum \([N]\) in shoot biomass required for maximum growth rate.
- \(N_c\) can also be defined as the min \([N]\) required to achieve max aboveground biomass (Lemaire and Salette, 1984).
- The relationship between \(N_c\) and biomass:
  \[N(\%) = aW^{-b}\]
  Where, \(W = \text{shoot biomass (t/ha)}, a\) and \(b\) are derived constant, e.g. \(N\% = 5.3W^{-0.44}\) for wheat.
- NNI vs. Leaf Chl or NNI vs. NDVI,
  e.g. \(\text{NNI} = -0.64 + 0.039\ \text{CM}\)
Drought Stress

- Drought is the major limiting factor for crop production
- Unpredicted stress
- Once every 4-5 years in past 50 years in NA.
- Annual losses =17% of total production
- Drought is dependent on the soil moisture content
Least Limiting Water Range
(LLWR = $\theta_{fdl} \cdot \theta_t$)

Crop growth rate
Photosynthesis

Max
90% Max

10% Max

Permanent wilt point/
Low limit

Field capacity
Upper limit

Total available water content

Threshold water content

Water Content (cm$^3$ cm$^{-3}$)

Least Limiting Water Range
(LLWR = $\theta_{fdl} \cdot \theta_t$)
WUE

• Definition: yield of plant product (Y) per unit of crop water use (ET), WUE = Y / ET

• ET = E (non-productive evaporation) + T

• Physiological WUE:
  – Leaf level: $WUE_L = \frac{P_N}{G_s}$
  – Canopy level: $WUE_P = \frac{BM}{ET}$
Salinity

- Salinity like drought, remains one of the world’s oldest and most serious problem for agriculture.

- Negatively affect many morphological, physiological and biochemical processes including seed germination, growth, yield and NUE of crop plants.

- Both salinity and drought reduce nitrate flux in roots and thus decrease nitrate reductase activity in leaves.

- In fact, there is scanty of information regarding the effect of salinity or water stress on N uptake and use efficiency, growth and yield of both hulless and hulled oat cultivars.
The main research objectives are:

- To identify critical N requirement and develop N application strategy for high grain yield of oat
- To assess the impact of drought and salinity on phenological, morphological, physiological processes, growth and yield of contrasting genotypes
- To explore the impact of salinity and drought on N uptake, partitioning, remobilization and N use efficiency of hulless and hulled oat cultivars
- To optimize agronomic measures and physiological processes to improve yield of hulless and hulled oats.
Materials and Methods

4 greenhouse and 1 field exps. to address the above-mentioned objectives. Here I describe one of the exps.

**Genotypes:** Prescott, VAO-2

**N treatments:**
- $T_1$, Control - N supply from seedling to PM
- $T_2$, N supply from seedling to flag leaf
- $T_3$, N supply from flag leaf to PM
- $T_4$, N supply from seedling to heading
- $T_5$, N supply from heading to PM.
Determining NUE and source of plant by $^{15}\text{N}$ labelling

<table>
<thead>
<tr>
<th>$\text{N treatment}$</th>
<th>Duration of Hoagland nutrient solution additions</th>
<th>$\text{Hoagland}$</th>
<th>$\text{Hoagland}$</th>
<th>Total N applied from $\text{Hoagland} - ^{15}\text{N}$ pulse</th>
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<td></td>
<td></td>
<td>nutrient</td>
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<td>36</td>
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<td>T₅</td>
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</table>

E⁻ FL     HD     PM
NUE was determined according to Subedi and Ma (2005b):

$$\text{NUE}(\%) = \frac{\sum_i [W_i \times N_i (^{15}N_{ni} - ^{15}N_{no})] \times 100}{f(a-b)}$$

Sources of plant total N, was originated from two major sources: the labelled NH$_4$NO$_3$ (Labelled-N) and the non-labelled source (Hoagland solution plus soil mix).

Labelled N % = total $^{15}$N x [100 / (5.20-0.37)] / total N x 100

Subtracting the labelled N% from 100%, to get the plant N originating from the non-labelled source.
<table>
<thead>
<tr>
<th>Source</th>
<th>Genotype (G)</th>
<th>N treatment (T)</th>
<th>G × T</th>
<th>Error</th>
<th>CV (%)</th>
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<td>T4</td>
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Related publications


Conclusions

● The naked oat had 21% greater total DM, 18% higher plant TN than the covered oat.
● N supply was more critical before heading.
● Overall, restriction of N supply from seeding to flag leaf stage reduced grain yield by 26%.
● Restriction of N supply from seedling to heading reduced yield by 65%, and N uptake by 75%.
● N partitioning towards grains lower in naked than in covered oat cultivar.
Conclusion cont’d

● N supplied from seedling to maturity, 61% more $^{15}$N in the shoots, but 46% less $^{15}$N in the grain of the naked than of the hulled variety.
● Withholding N supply until flag leaf stage increased $^{15}$N in the grain, resulting in the highest NUE.
● A larger portion of N was derived from the labelled source in the naked than the covered oats.
● Higher NUE in VAO-2 was associated with N in the vegetative tissues, partitioning of N to the grain in VAO-2 was less efficient.
● Early N supply is critical for both grain yield and total N uptake.
● Enhancing N utilization efficiency is important for naked oat yield and NUE improvement.
Thanks!