Model Analysis of Crabgrass Response to Applied Nitrogen

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ABSTRACT

The extended logistic model of crop response to applied nutrients provides quantitative coupling of seasonal dry matter ($Y$), plant N uptake ($Nu$), and plant N concentration ($Nc$) with applied nutrient ($N$). It predicts a hyperbolic relationship between $Y$ and $Nc$ with $Nu$. Analysis of data from numerous studies has confirmed the model. In this article the model was applied to data for crabgrass ($Digitaria sanguinalis$) grown at Ardmore, OK. Results showed that single applications of nitrogen provided greater yields and plant N uptake over split applications. The difference was accounted for in the linear parameters for yield ($A$) and

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for plant N uptake ($A_n$). Applied N required to achieve 50% of maximum yield was 57 kg ha$^{-1}$ and for 50% of maximum plant N uptake was 110 kg ha$^{-1}$.

**Key Words:** Model; Nitrogen; Grass.

## INTRODUCTION

Overman et al.[1] have published an extended logistic model of forage grass response to applied N. The model includes functions for dry matter and plant N accumulation over the growing season. Data from the literature[2] for dallisgrass (*Paspalum dilatatum* Poir) were used to illustrate characteristics of the model. The model has been applied to the annual corn (*Zea mays* L.) as well.[3] In this analysis, the model is used to evaluate model parameters for crabgrass response to applied nitrogen for single and split applications.

## MODEL DESCRIPTION

In the extended logistic model seasonal dry matter yield ($Y$), plant N uptake ($N_u$), and plant N concentration ($N_c$) are related to applied nitrogen ($N$) by the equations

$$Y = \frac{A}{1 + \exp(b - cN)} \quad (1)$$

$$N_u = \frac{A_n}{1 + \exp(b_n - cN)} \quad (2)$$

$$N_c = \frac{N_u}{Y} = N_{cm} \left[ \frac{1 + \exp(b - cN)}{1 + \exp(b_n - cN)} \right] \quad (3)$$

where $A$=maximum yield at high $N$, Mg ha$^{-1}$; $A_n$=maximum plant N uptake at high $N$, kg ha$^{-1}$; $N_{cm}$=$A_n/A$=maximum plant N concentration at high $N$, g kg$^{-1}$; $b$=intercept parameter for yield; $b_n$=intercept parameter for plant N uptake; $c$=response coefficient for applied N, ha kg$^{-1}$. The phase relation follows from Eqs. 1 and 2 and is given by

$$Y = \frac{Ya N_u}{K_n + N_u} \quad (4)$$
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where the phase parameters are related to logistic parameters by

\[ Y_m = \frac{A}{1 - \exp(-\Delta b)} \]  

(5)

\[ K_n = \frac{A_n}{\exp(\Delta b) - 1} \]  

(6)

with the definition

\[ \Delta b = b_n - b \]  

(7)

Now Eq. 4 can be rearranged to the linear relationship between plant N concentration \((N_c)\) and plant N uptake \((N_u)\)

\[ N_c = \frac{N_u}{Y} = \frac{K_n}{Y_m} + \frac{1}{Y_m}N_u \]  

(8)

DATA ANALYSIS

Data for this analysis are taken from a field study by Dalrymple[4]. Crabgrass was grown on Stephenville fine sandy loam (fine loamy, siliceous, active, thermic Ultic Haplustalfs) near Ardmore, OK. Treatments included applied nitrogen rates of 0, 34, 67, 134, and 268 kg ha\(^{-1}\). Single applications were made on 28 May 1975. For the split applications, the second application was made on 24 June 1975 immediately following the first harvest. Treatments were replicated three times. Measurements were made of dry matter and plant N. Results are listed in Table 1 and shown in Figure 1.

<table>
<thead>
<tr>
<th>N kg ha(^{-1})</th>
<th>(Y) Mg ha(^{-1})</th>
<th>(N_c) g kg(^{-1})</th>
<th>(N_u) kg ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>Split</td>
<td>Single</td>
<td>Split</td>
</tr>
<tr>
<td>0</td>
<td>2.70</td>
<td>2.70</td>
<td>15.2</td>
</tr>
<tr>
<td>34</td>
<td>3.10</td>
<td>2.95</td>
<td>17.6</td>
</tr>
<tr>
<td>68</td>
<td>4.87</td>
<td>4.16</td>
<td>19.4</td>
</tr>
<tr>
<td>134</td>
<td>6.84</td>
<td>5.85</td>
<td>25.9</td>
</tr>
<tr>
<td>268</td>
<td>7.91</td>
<td>7.58</td>
<td>31.5</td>
</tr>
</tbody>
</table>

Data adapted from Ref. [4].
Figure 1. Response of seasonal dry matter ($Y$), plant N uptake ($N_u$), and plant N concentration ($N_c$) to applied nitrogen ($N$) for crabgrass grown at Ardmore, OK. Data adapted from Dalrymple.\cite{4} Curves drawn from Eqs. 9–14.
Model parameters in Eqs. 1–3 were estimated by a trial-and-error approach. The resulting equations are:

**Single application**:

\[
Y = \frac{8.40}{1 + \exp(0.85 - 0.0150N)}
\]

\[
N_u = \frac{270}{1 + \exp(1.65 - 0.0150N)}
\]

\[
N_c = 32.1 \left[ \frac{1 + \exp(0.85 - 0.0150N)}{1 + \exp(1.65 - 0.0150N)} \right]
\]

**Split applications**:

\[
Y = \frac{7.70}{1 + \exp(0.85 - 0.0150N)}
\]

\[
N_u = \frac{195}{1 + \exp(1.65 - 0.0150N)}
\]

\[
N_c = 25.3 \left[ \frac{1 + \exp(0.85 - 0.0150N)}{1 + \exp(1.65 - 0.0150N)} \right]/C_{20}/C_{21}
\]

The logistic parameters can then be substituted into Eqs. 6 and 7 to obtain the phase parameters and relations:

**Single application**:

\[
Y = \frac{15.2N_u}{220 + N_u}
\]

\[
N_c = \frac{N_u}{Y} = 14.5 + 0.0658N_u
\]

**Split applications**:

\[
Y = \frac{14.0N_u}{159 + N_u}
\]

\[
N_c = \frac{N_u}{Y} = 11.4 + 0.0714N_u
\]

Results are shown in Figure 2.
DISCUSSION

The extended logistic model provides excellent description of crop response to applied N for both single and split applications (Figure 1). Differences in single vs. split applications are accounted for in the linear parameters $A$, $A_n$, and $N_{cm}$. The exponential parameters $b$, $b_m$, and $c$ are
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common to both. Efficiency of plant utilization of applied N is 38% greater for single vs. split applications, and results in a 27% increase in crude protein. Data for the phase relations ($Y$ and $N_c$ vs. $N_u$) given by Eqs. 4 and 8 follow the model (Figure 2).

It can be shown from the model that the level of applied N to achieve 50% of maximum yield is given by

$$Y = A \frac{N}{2} \quad N = N_{1/2} = \frac{b}{c}$$

which is 57 kg ha$^{-1}$ in this case. The corresponding level for 50% of maximum plant N uptake is 110 kg ha$^{-1}$.

For this low fertility soil (Stephenville fine sandy loam), the estimated maximum dry matter yield was 8.40 Mg ha$^{-1}$. From a companion study by Dalrymple[5] on a high fertility soil Norwood fine sandy clay loam (fine-silty, mixed, superactive, hyperthermic Fluventic Eutrudepts) near Burneyville, OK, we can estimate maximum yield as approximately 9.00 Mg ha$^{-1}$. Yields approach similar maxima for the two soils at high-applied N.

The broad subject of production and evaluation of crabgrass for forage, including management and economics, has been discussed by Dalrymple and associates.[6]

REFERENCES