Soybean Physiology: How Well Do You Know Soybeans?

Shaun Casteel, Purdue University
Soybean Extension Specialist

www.soybeanstation.org
Soybean Germination

- How many nodes are present in the seed?
  - Cotyledon, Unifoliate, 1st Trifoliate
- Cell division initiates within ~36 to 48 h of imbibition
- Radicle is first to emerge
  - Water content equals ~50% of seed weight
  - Moisture & Temp dependent
- Hypocotyl pull cotyledons
Hypocotyl Pulls the Cotyledons (Seed Leaves) Out of the Soil
VE – Emergence: cotyledons and growing point are above the soil surface

5 to 21 days after planting

hypocotyl
cotyledons
Soil Temperature & Seedling Growth

• 50 F soil is the accepted low soil temp
  – Some soybeans have germinated in 36 to 43 F
• Time to soybean germination & emergence can be related to heat unit accumulation.
  – Growing Degree Days (GDDs)
Soybean Emergence after 90 GDDs

<table>
<thead>
<tr>
<th>Plant Stand (1000s/acre)</th>
<th>30-Mar</th>
<th>13-Apr</th>
<th>27-Apr</th>
<th>10-May</th>
<th>30-May</th>
<th>6-Jun</th>
</tr>
</thead>
<tbody>
<tr>
<td>81%</td>
<td>23 d</td>
<td>70%</td>
<td>96%</td>
<td>87%</td>
<td>83%</td>
<td>63%</td>
</tr>
</tbody>
</table>

Planting Date

West Lafayette, IN
Percent Emergence by Seed Size

Conley, 2009 unpublished
VC – Cotyledons and Unifoliates Are Fully Expanded
VC – Cotyledons and Unifoliates Are Fully Expanded

- Cotyledons supply the nutrient needs of the seedling for ~7-10 days
  - Seed reserves + photosynthesis by the green cotyledons
  - Cotyledons lose ~70% of their dry weight from this nutrient allocation

- Unifoliates are opposite
Soil Crusting

Swollen hypocotyl

No cotyledons

• Loss of both cotyledons can reduce yield 2 to 7%
V1 – First Trifoliate

- Fully developed unifoliate leaves
- 1 unrolled trifoliate
  - Single, Alternating
  - Leaflets do not touch
V2 – Second Trifoliolate

- 2 unrolled trifoliates
  - Single, Alternating
  - Leaflets do not touch

- 2nd trifoliate was initiated ~3 to 4 days after germination

- Active N₂ fixation
V2 – Active N$_2$ Fixation

- *Bradyrhizobia japonicum* penetrate root and establish N$_2$-fixing nodules
- Attach to epidermal cells in the actively growing region just behind the root cap.
  - Usually with immature or unformed root hairs
- Mature nodules – 28 days after infection
- Maximum size – 28 to 37 days after infection
- Degeneration – 50 to 60 days after infection
# Nutrient UPTAKE: Soybean vs. Corn

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soybean</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grain</td>
<td>3.8</td>
<td>0.84</td>
<td>1.3</td>
</tr>
<tr>
<td>Stover</td>
<td>1.1</td>
<td>0.24</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>4.9</td>
<td>1.08</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>Corn</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grain</td>
<td>0.9</td>
<td>0.38</td>
<td>0.27</td>
</tr>
<tr>
<td>Stover</td>
<td>0.45</td>
<td>0.16</td>
<td>1.1</td>
</tr>
<tr>
<td>Total</td>
<td>1.35</td>
<td>0.54</td>
<td>1.37</td>
</tr>
</tbody>
</table>
## Nutrient REMOVAL: Soybean vs. Corn

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soybean – 60 bu</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grain</td>
<td>228</td>
<td>50.4</td>
<td>78</td>
</tr>
<tr>
<td>Stover</td>
<td>66</td>
<td>14.4</td>
<td>60</td>
</tr>
<tr>
<td>Total</td>
<td>294</td>
<td>64.8</td>
<td>138</td>
</tr>
<tr>
<td><strong>Corn – 180 bu</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grain</td>
<td>162</td>
<td>68.4</td>
<td>48.6</td>
</tr>
<tr>
<td>Stover</td>
<td>81</td>
<td>28.8</td>
<td>198</td>
</tr>
<tr>
<td>Total</td>
<td>243</td>
<td>97.2</td>
<td>246.6</td>
</tr>
</tbody>
</table>
Effect of Node Removal at V2 and V5 on Grain Yield in 2004

![Graph showing the effect of node removal on grain yield at V2 and V5. The x-axis represents percent node removal, ranging from 0 to 100, and the y-axis represents percent of max yield, ranging from 0 to 100. The graph includes data points for removal at V-2 and V-5, with a downward trend indicating decreased yield as removal increases.]
V5 – Fifth Trifoliate

- 5 unrolled trifoliates
  - Single, Alternating
  - Leaflets do not touch
- VC to V5: new V stage every ~5 to 7 days
  - Root growth as much as ~0.5 to 0.75 inch per day (Kasper et al., 1976)
- V5 to R5: new V stage every ~3 to 5 days
# of Nodes Initiated on Main Stem

<table>
<thead>
<tr>
<th>Node Count</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Planting</td>
</tr>
<tr>
<td>3</td>
<td>Emergence</td>
</tr>
<tr>
<td>4</td>
<td>Unifoliate</td>
</tr>
<tr>
<td>~8</td>
<td>1st Trifoliate</td>
</tr>
<tr>
<td>~12</td>
<td>3rd Trifoliate</td>
</tr>
<tr>
<td>~15</td>
<td>5th Trifoliate</td>
</tr>
<tr>
<td>~19</td>
<td>Fully Expanded</td>
</tr>
</tbody>
</table>

Johnson et al., 1960
<table>
<thead>
<tr>
<th>Reproductive Stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1: Beginning Bloom</td>
</tr>
<tr>
<td>R2: Full Bloom</td>
</tr>
<tr>
<td>R3: Beginning Pod</td>
</tr>
<tr>
<td>R4: Full Pod</td>
</tr>
<tr>
<td>R5: Beginning Seed</td>
</tr>
<tr>
<td>R6: Full Seed</td>
</tr>
<tr>
<td>R7: Beginning Maturity</td>
</tr>
<tr>
<td>R8: Full Maturity</td>
</tr>
</tbody>
</table>
R1: Beginning Bloom

- Open flower at **any node on the main stem**
- Flowering begins at 3rd to 6th node (V6 to V10 stage)
- Flowering period is 3 to 4 wk
  - Begins ~6 to 8 wk after emergence
  - Peaks R2 to R3; ends ~R5
- **Vertical root growth rates increase rapidly**
  - As much as 1.3 to 3.2 in/day (Kasper et al., 1976)

~Days to R7 - 70
# of Days from Planting to R1

- **03/30**: 82 days
- **04/13**: 68 days
- **04/27**: 66 days
- **05/10**: 54 days
- **05/30**: 46 days
- **06/06**: 43 days

**Plants to Reach R1**

- **20-Jun**: ~520 GDDs
- **~2-Jul**: ~17-Jul

West Lafayette, IN
Yield Effects of Weed Removal by Row Width

Yield Loss (% weed free)

Timing of weed removal (Soybean stage)

V1, V2, V3, V4, V5, V6, V7, R1, R2, R3

7.5", 15", 30"
R2: Full Bloom

• Open flower at one of two uppermost main-stem nodes
• Accumulated 25% of total dry wt & 50% of total node #
• Rapid dry wt and nutrient accumulation from R2 until R7 initiation
• N-fixation rate ↑
• 50% defoliation ↓ yield 60%

~Days to R7 - 65
R3: Beginning Pod

Any pod that is \(~3/16\) inch long and is on one of the four uppermost nodes of the main stem.

Developing pods, withering flowers, open flowers, & flower buds can all be found during this stage.
R3: Beginning Pod

• A 3/16 inch long pod at one of the four uppermost nodes on the main stem

• Yield is a function of:
  – Base population
  – Pod number
  – Seeds per pod
  – Seed weight

• Ability to compensate for stress by modifying these factors decreases from R1 to R5

~Days to R7 - 55
R4: Full Pod

- A 3/4 inch pod at one of the four uppermost nodes on the main stem
- Rapid pod growth & beginning seed development
- From R4 to middle R5 critical for yield
  - Rapid and steady dry matter accumulation
  - Flowering is complete
  - Young seeds & pods are most prone to abortion
- Yield reduction based on total pod # is the main yield limiting factor
  - ↓ Seed # per pod and seed size may also occur

~Days to R7 - 45
Planting Date Effect on Pod Number Plant$^{-1}$

Pod number plant$^{-1}$

<table>
<thead>
<tr>
<th>Planting Date</th>
<th>Pod number plant$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/30</td>
<td>A</td>
</tr>
<tr>
<td>04/13</td>
<td>A</td>
</tr>
<tr>
<td>04/27</td>
<td>A</td>
</tr>
<tr>
<td>05/10</td>
<td>A</td>
</tr>
<tr>
<td>05/30</td>
<td>AB</td>
</tr>
<tr>
<td>06/06</td>
<td>B</td>
</tr>
</tbody>
</table>

West Lafayette, IN
R5: Beginning Seed

Seed is $\frac{1}{8}$ inch long in a pod at one of four uppermost nodes on main stem.

~Days to R7 - 35
R5: Beginning Seed

- Seed is $1/8^{th}$ inch long in a pod at one of four uppermost nodes on main stem
- Rapid seed filling and redistribution of dry matter/nutrients occur
- Root growth slows as seed growth begins
- Midway between R5 and R6
  - Maximum height
  - Maximum node number
  - Maximum leaf area
  - N-fixation rate peaks then rapidly ↓

~Days to R7 - 35
Planting Date Effect on Node Number Plant$^{-1}$

Node number plant$^{-1}$

<table>
<thead>
<tr>
<th>Planting Date</th>
<th>Node Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/30</td>
<td>A</td>
</tr>
<tr>
<td>04/13</td>
<td>A</td>
</tr>
<tr>
<td>04/27</td>
<td>A</td>
</tr>
<tr>
<td>05/10</td>
<td>A</td>
</tr>
<tr>
<td>05/30</td>
<td>B</td>
</tr>
<tr>
<td>06/06</td>
<td>B</td>
</tr>
</tbody>
</table>
A pod containing a **green seed that fills the pod capacity** is located at one of the four uppermost main stem nodes.

~Days to R7 - 20
R6: Full Seed

• A pod containing a green seed that fills the pod capacity is located at one of the four uppermost main stem nodes.

• Total plant pod weight is maximized

• Rate of dry weight and nutrient accumulation slows

• Root growth is complete between R6 and R7

~Days to R7 - 20
Planting Date Effect on Seed Size

Seed wt. (g 100⁻¹ seed)

<table>
<thead>
<tr>
<th>Planting Date</th>
<th>Seed wt.</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/30</td>
<td>15</td>
<td>B</td>
</tr>
<tr>
<td>04/13</td>
<td>17</td>
<td>B</td>
</tr>
<tr>
<td>04/27</td>
<td>14</td>
<td>A</td>
</tr>
<tr>
<td>05/10</td>
<td>17</td>
<td>A</td>
</tr>
<tr>
<td>05/30</td>
<td>17</td>
<td>A</td>
</tr>
<tr>
<td>06/06</td>
<td>18</td>
<td>A</td>
</tr>
</tbody>
</table>

~3000 seeds/lb
~2700 seeds/lb
R7: Beginning Maturity

Plants shedding leaves just prior to R7

One pod anywhere with mature color
R8: Full Maturity

- 95% of pods reached mature color
- ~35% grain moisture in freshly matured pod
- ~15% within another 5 to 10 days
- Below-optimum plant stands cause more branching, low pod heights & can delay maturity
- Above-optimum plant stands increase lodging
Figure 11. Development and timing of vegetative growth, flowering, pod development, and seed filling.
Any Questions?

Shaun Casteel
765-494-0895
scasteel@purdue.edu
www.soybeanstation.org