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Minnesota Crop Production Retailers Association Trade Show

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Maximizing Soybean Yield: Genetics, Nutrition, and Management

Larry C. Purcell & Ryan Van Roekel
University of Arkansas & DuPont Pioneer

CPM Short Course and MCPR Trade Show
Minneapolis, MN December 11, 2014
• Arkansas Soybean Promotion Board
• DuPont Pioneer
• Grower Cooperators
  – Kip Cullers
  – Dow Brantley
  – Michael Taylor
  – Stan Haigwood
  • Randy Chlapecka
• Introduction
  – Management and framework for increasing seed number and seed size

• Research in Mr. Cullers’ contest field

• Small plot research at Fayetteville

• Large strip trials
Variety Selection

Fayetteville 2013 – 42 bushel range
TN, AR, MS, & LA 2003-08
+3.5 bushel avg. response
80% positive net return
Assume: 38% protein

HI=0.45, 1% N stover

365 lb N ac⁻¹
Assume: 38% protein
HI=0.45, 1% N stover

103 lb N ac$^{-1}$
Assume: 38% protein
HI=0.45, 1% N stover

Grain yield (bu acre$^{-1}$)

Grain
Stover
Total

468 lb N ac$^{-1}$
Nutrient Requirements
101 Bushel/Acre Soybean
(Flannery, 1986; 1989)

<table>
<thead>
<tr>
<th></th>
<th>Total Uptake at Maturity (lb/A)</th>
<th>Nutrient Removal with Grain (lb/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P₂O₅</td>
</tr>
<tr>
<td>Total Uptake</td>
<td>494</td>
<td>112</td>
</tr>
<tr>
<td>Nutrient Removal</td>
<td>323</td>
<td>87.2</td>
</tr>
</tbody>
</table>
Don’t Forget

- Planting date
- Irrigation application timing, method, duration & amount
- Weed control
- Insect control
- Stand establishment & plant density
- Nematodes
- Crop rotation
- Herbicide carry-over
- Drainage
- Compaction
- Rooting restrictions
- pH
- Salinity
- Harvest loss
Yield \( (g \, m^{-2}) \) =
- seed number \( (\text{seed} \, m^{-2}) \times \)
- average seed weight \( (g \, \text{seed}^{-1}) \)

Hypothesis:
- seed number is determined during flowering and pod formation and is limited by sugars produced during photosynthesis
- average seed weight is determined by the duration of the seed fill period and is limited by nutrient availability.
Seed number – Charles Edwards model

\[
\left\{ \begin{align*}
\text{Total crop growth rate} & = \text{Fraction of total sugar partitioned to seed} \\
& \div \text{Minimum amount of sugar per day needed to keep a seed from aborting}
\end{align*} \right.
\]
Total crop growth rate, CGR

Sugar per seed, SGR

\[
\text{Seed number} \div \text{Duration of seed growth} \times \text{Seed growth rate} = \text{Yield}
\]
Large seed number:

- high growth rates R1 to R5
- low seed growth rates

Large average seed weight:

- low seed growth rates
- long seedfill period
- not limited by nutrition
Total crop growth during flowering early seed fill (g sugar m^{-2} d^{-1})

How can we increase the size of this block of sugar?

- Match planting date and variety such that flowering begins before the solstice
- Manage row spacing and population density so that full light interception occurs at beginning flowering
Solar radiation (MJ m$^{-2}$ d$^{-1}$)

Emg R1 R5 R6 R7 R8
• Introduction
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• Large strip trials
Current Yield Record

- Mr. Kip Cullers, Missouri Soybean Association
  - 2006 – 139 bu/ac
  - 2007 – 155 bu/ac
  - 2008 – 118 bu/ac
  - 2009 – N/A
  - 2010 – 161 bu/ac
  - 2011 – 109 bu/ac
  - 2012 – N/A
  - 2013 – 115 bu/ac

Research with Cullers

- Establish four plots within each variety
  - Radiation use efficiency
  - N accumulation rate
  - Seed growth rate and seed fill duration
Rotates between two contest fields of Newtonia silt loam
Perennial poultry litter applications
Early planting
Plant density ~140,000 plants/acre
9 inch twin rows on 30 inch centers with a Monosem planter
Indeterminate Pioneer Hi-Bred varieties from 4.2 – 5.1 RM
Frequent (daily) overhead irrigation
Multiple seed treatments, herbicides, insecticides, fungicides, and others…
• Severe heat and drought in 2012
• Late planting (May 27th) in 2013
• No supplemental fertigation
Seed number and seed weight

- Cullers seed weight ~2900 seeds/lb
- In years with yields >150 bu/ac, seed weight ~2000 seeds/lb
- If you maintain same seed number at 110 bu/ac and increase seed weight, increase yield to 160 bu/ac
N Accum Rate & RUE

- N accumulation rate (NAR) with a full canopy
- Radiation use efficiency (RUE) during vegetative growth
- Both NAR and RUE are highest ever reported for soybean

<table>
<thead>
<tr>
<th>Variety</th>
<th>NAR</th>
<th>RUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>94B73</td>
<td>1.88 AB</td>
<td>1.89 A</td>
</tr>
<tr>
<td>94Y80</td>
<td>1.66 AB</td>
<td>1.73 A</td>
</tr>
<tr>
<td>48T53</td>
<td>1.43 B</td>
<td>1.46 B</td>
</tr>
<tr>
<td>49T97</td>
<td>2.08 A</td>
<td>1.89 A</td>
</tr>
<tr>
<td>50T40</td>
<td>2.07 A</td>
<td>1.80 A</td>
</tr>
<tr>
<td>5332</td>
<td>1.51 B</td>
<td>1.83 A</td>
</tr>
</tbody>
</table>

2013

Van Roekel and Purcell. 2014. Crop Sci. 54:1189

<10% of N was derived from N₂ fixation
Average seed weight

Duration of seed growth \times \text{Seed growth rate} = \text{Average seed weight}

- Slower seed fill = less amount of sugar and nutrients needed per seed per day
Rate HI increase typically $\approx 0.013$

Typical seed fill for 30 to 35 days

Lower rates and longer durations:
- Prevent seed/pod abortion
- Minimizes demand on leaf proteins (N)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Rate HI Increase</th>
<th>Seed Fill Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>94B73</td>
<td>0.0082 D</td>
<td>45.8 A</td>
</tr>
<tr>
<td>94Y80</td>
<td>0.0138 A</td>
<td>34.0 C</td>
</tr>
<tr>
<td>48T53</td>
<td>0.0105 C</td>
<td>31.2 CD</td>
</tr>
<tr>
<td>49T97</td>
<td>0.0132 AB</td>
<td>28.8 D</td>
</tr>
<tr>
<td>50T40</td>
<td>0.0103 C</td>
<td>39.8 BC</td>
</tr>
<tr>
<td>5332</td>
<td>0.0111 BC</td>
<td>36.4 BC</td>
</tr>
</tbody>
</table>
Conclusions

• Early flowering and full light interception maximizes amount of photosynthate produced
• High N accumulation rate creates large pool of available N
• Long seed fill duration lessens photosynthate and N demand for each individual seed
  – All work together to increase seed (pod) number and seed weight
• Introduction
  – Management and framework for increasing seed number and seed size

• Research in Mr. Cullers’ contest field

• Small plot research at Fayetteville

• Large strip trials
Soil test recommendations (x2)
5 to 7.5 tons/ac dry poultry litter
Deep tillage ≥ 14 inches
Early planting
18 in row width
~140,000 plants ac⁻¹
Sprinkler irrigation @ 1-inch deficient
N, K, & S fertigation

Total irrigation: 25 inches
Litter + pre-season (lb ac⁻¹):
  - N, 697
  - P, 272
  - K, 563
  - S, 80
  - Mg, 28
Fertigation (lb ac⁻¹):
  - N, 159
  - K, 36
  - S, 10

Van Roekel and Purcell. Unpublished results.
Fayetteville 2012

Yield (bu/ac)

P94Y23 115 A
AG5332 107 A
P94Y80 106 B
P94Y81 105 C
AG4907 104 A
S46-U6 100 B
AG4303 99 C
AG5503 97 C
AG4531 96 C
P94Y82 96 C
S44-K7 95 C
S49-A5 86 D
Fayetteville 2013

Planted May 14th, 125,000 plants per acre
Treatments Evaluated

- P94Y81 and AG4907 in 2011-12
- P47T36 and AG4632 in 2013
  - Herbicide burn at V3
  - Kip’s seed treatments
  - Thinned to even spacing or emergence
• Applied at V3
• Early morning with dew to increase injury
• Products & rates:
  - 0.5 oz/ac Aim + NIS
  - 0.9 oz/ac Cadet + NIS
  - 12.5 oz/ac Cobra + NIS
  - 12.5 oz/ac Cobra + 2% crop oil
  - 12.5 oz/ac Cobra + 0.5 oz/ac Aim + 2% crop oil

Yield (bu/ac)

<table>
<thead>
<tr>
<th></th>
<th>Untreated Check</th>
<th>Cobra</th>
<th>Cobra+CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (bu/ac)</td>
<td>100</td>
<td>91</td>
<td>94</td>
</tr>
</tbody>
</table>

Non-significant
Seed Treatments

• “Untreated” (came with fungicide/insecticide)
• Optimize 400 (2x rate)
  − Novozymes, Bradyrhizobium + lipo-chitooligosaccharide (LCO), “biological molecule stimulates cell division & growth”
• Bio-Forge
  − Stoller, N,N'-diformyl urea, “upregulate anti-oxidative pathways, reduce plant stress”
• Accolade-(P)
  − INTX Microbials, Azospirillum brasilense, free-living N₂ fixing bacteria
• Treated control – all of the above
Seed Treatments, 2011-13

Yield (bu/ac)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Untreated&quot; Control</td>
<td>95</td>
</tr>
<tr>
<td>Accolade only</td>
<td>92</td>
</tr>
<tr>
<td>Optimize only</td>
<td>94</td>
</tr>
<tr>
<td>Bio-Forge only</td>
<td>97</td>
</tr>
<tr>
<td>Treated Control</td>
<td>100</td>
</tr>
</tbody>
</table>

Non-significant
Even Spacing or Emergence

- No response to even intra-row spacing or even height
- Likely due to soybean’s ability to “flex”
Conclusions

- No single practice increased yield beyond described maximum yield management:
  - Plant early
  - Soil test recommendations (x2)
  - 5 to 7.5 dry tons/ac poultry litter
  - Deep tillage ≥ 14 in.
  - Early planting
  - 18 inch rows
  - 140,000 plants/ac
  - Sprinkler irrigation @ 1 in. deficient
  - N, K, & S fertigation
  - Preventative fungicides
  - Strict pest control
• Introduction
  – Management and framework for increasing seed number and seed size

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Objective

• Demonstrate management practices for high soybean yield in large production fields
  – Reach 100 bu/ac without significantly increasing input costs
• Three (2012-13) locations in Eastern Arkansas
• Five or six Pioneer cultivars
  – 4.2 to 5.1 RM
  – Indeterminate
  – Glyphosate resistant
• Randomized 1-acre strips with 5-6 replications
Management

- Supplemental poultry litter (~1.5 dry tons/ac)
- Early planting (March 29-April 25)
- Row widths ≤ 30”
- Timely irrigation
- Strict pest management
  - Pre-plant residual + post herbicides
  - Reduced insect action thresholds
  - Two preventative fungicides
- 50 lbs N at R4 & R5.5 (2012-13)
## 2013 Cultivar Yield

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>England</th>
<th>Helena</th>
<th>Newport</th>
</tr>
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<tr>
<td></td>
<td>__________</td>
<td>bu/ac</td>
<td>__________</td>
</tr>
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<td>.</td>
<td>.</td>
<td>96 B</td>
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<tr>
<td>94Y40</td>
<td>100 B</td>
<td>76 C</td>
<td>92 C</td>
</tr>
<tr>
<td>46T21</td>
<td>103 A</td>
<td>88 A</td>
<td>98 AB</td>
</tr>
<tr>
<td>94Y70</td>
<td>99 B</td>
<td>84 B</td>
<td>91 CD</td>
</tr>
<tr>
<td>48T53</td>
<td>104 A</td>
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</tr>
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<td>92 C</td>
<td>90 A</td>
<td>89 D</td>
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2013 Cultivar Yield

bu/ac
## 2013 Cultivar Yield

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Economic Costs

• Costs above growers’ normal practices

Per acre:

- Poultry litter $80
- Urea $75
- 2nd Fungicide $20
- Defoliant $15

$190

“Normal practices” in nearby fields were 8 to 9 bu/ac less

$10/bushel = $80 to $90 response per acre
Break-even Yield Response

- Graph shows the relationship between Grain Price ($ per bu) and Bushels to Break Even.
- As Grain Price increases, the Bushels to Break Even decreases.
Conclusions

- **Early planting & narrow rows** to set pods
- **Irrigation, fertility & pest control** to keep pods
- **Don’t forget basics** (variety, compaction, pH…)
- **N₂ fixation** most profitable
- **Attention to detail & timing** of everyday agronomics capable of 80 bu/ac (100+ with weather & luck)
Thank You