Auxin Herbicides in Cotton

Bill McCloskey
Extension Weed Science
New Herbicide Resistant Cotton Technology

• Dicamba resistant cotton - Monsanto & BASF
  – Engenia (BASF) – dicamba alone (BAPMA, tridentate amine salt)
  – XtendiMax (Monsanto) – dicamba alone (DG or diglycolamine salt + proprietary technology to reduce volatility)
  – Roundup Extend – monoethanolamine glyphosate + DG dicamba
  – State (AZ) labels for Engenia, XtendiMax in 2017 cotton crop.

• 2,4-D resistant cotton – Dow
  – Enlist – 2,4-D:choline formulation
    Enlist Duo – 2,4-D:choline + glyphosate
  – AZ label excludes: Yuma, La Paz, Maricopa, Pinal, Pima and Santa Cruz Counties (January 2017)

• Stacked with glyphosate and glufosinate
A Season to Remember:
Our Experiences with Off-Target Movement of Dicamba in 2016

Kevin Bradley
University of Missouri
~45,000 acres soybean “officially” damaged

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How about “unofficial” damage?
~ 100,000 acres ???

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2 acres fresh market tomatoes
9 acres cantaloupe

©Kevin Bradley, University of Missouri
32 acres watermelon

©Kevin Bradley, University of Missouri
32 acres watermelon

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400 acres purple hull peas
~900 acres of peaches
And many, many homeowner gardens, trees, ornamental bushes, etc.
Some common themes in the off-site movement of dicamba in Missouri.
Both the DMA (Banvel, Rifle, etc.) and DGA (Clarity, Sterling Blue, etc.) salts of dicamba were sprayed.
The Dicamba Salt Matters...

Relative Volatility of Three Salts of Dicamba

- DMA (Banvel)
- DGA (Clarity, etc)
- BAPMA (Engenia)

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The rates of dicamba sprayed were often higher than 16 ozs/A.
Factors that Contributed to the Problem

• Various crops/traits/herbicides that are in very close proximity and don’t necessarily play well together
Soybeans

Cotton

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Factors that Contributed to the Problem

- Application parameters on the newly approved dicamba labels were almost certainly not followed (boom height, nozzles, etc.)

- Some sprayed at night...
#1 Factor that Contributed to the Herbicide Injury Problems Observed in 2016

A lack of appreciation for the inherent sensitivity of soybean to *extremely* low concentrations of dicamba.

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A Meta-Analysis on the Effects of 2,4-D and Dicamba Drift on Soybean and Cotton

J. Franklin Egan, Kathryn M. Barlow, and David A. Mortensen


Dicamba $n = 42, 18, 19$

2,4-D $n = 117, 76, 75, 64$
New Chemistry for Cotton Weeds in 2017

- Herbicide Resistant Weeds → New Herbicides
- 2,4-D+choline & dicamba salts
- Concerns – Volatility & Drift
- Misapplication
- Sprayer Cleanout
- Tank mixing
- Stewardship of technology
2,4-D choline
Enlist Duo: 2,4-D + glyphosate

Dicamba

Engenia

BAPMA
N-Bis-(aminopropyl) methylamine salt

Diglycolamine salt

XtendiMax with Vapor Grip Technology
Auxin mimic or Growth Regulator Herbicides: 2,4-D and Dicamba

- 2,4-D moves to shoot meristems (buds) with sugars, interacts with the auxin plant hormone system.
Auxin mimic or Growth Regulator Herbicides: 2,4-D and Dicamba

- Abnormal growth caused by phenoxy-type growth regulator herbicides.

Grape stem - triclopyr

Grape leaf – 2,4-D
Concerns: Off-target movement

• Volatility
• Spray droplet drift – Nozzle technology
Concerns: Volatility

- DO NOT add AMS, acid or any source of H to tank

![化学结构图](image1.png)

- More volatile
- AMS, UAN or Acid
- Low volatility
- BAPMA

- Low pH
- pK_a = 2.73
- pK_a = 1.97

- High pH > 7

- choline
Dicamba (0.5 lb ae/A) injury on cotton

Dicamba 7 DAT

Dicamba 14 DAT
Dicamba @ 1x rate or 0.5 lb ae/A
2 weeks after application @ 1\textsuperscript{st} square
38.5\% yield reduction (1,378 \textit{versus} 2,241 lb. lint/A)
Dicamba @ 1x rate or 0.5 lb ae/A
2 weeks after application @ 1st square
38.5% yield reduction (1,378 versus 2,241 lb. lint/A)
Dicamba @ 1/10x rate or 0.05 lb ae/A
(1x = 0.5 lb ae/A)
2 weeks after application @ 1st square
13.2% yield reduction (1,946 versus 2,241 lb. lint/A)
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Dicamba @ 1/10x rate or 0.05 lb ae/A 2 weeks after application @ 1st square 13.2% yield reduction (1,946 versus 2,241 lb. lint/A)
Dicamba @ 1/50x rate or 0.01 lb ae/A  
(1x = 0.5 lb ae/A)  
2 weeks after application @ 1st square  
1.53% yield reduction (2,207 versus 2,241 lb. lint/A)
Dicamba @ 1/50x rate or 0.01 lb ae/A
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2 weeks after application @ 1st square
1.53% yield reduction (2,207 versus 2,241 lb. lint/A)
Dicamba @ 1/50x rate or 0.01 lb ae/A
(1x = 0.5 lb ae/A)
2 weeks after application @ 1st square
1.53% yield reduction (2,207 versus 2,241 lb. lint/A; N.S.)
Dicamba effect on cotton lint yield at various rates and growth stages.  
UA Red Rock Agricultural Center – 2016  
Planted 4/20/2016

<table>
<thead>
<tr>
<th>Treat.</th>
<th>Rate</th>
<th>1st Square</th>
<th>1st Square + 2 weeks</th>
<th>1st Flower</th>
<th>1st Flower + 2 weeks</th>
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<td>(lb. lint/A)</td>
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<td>2,290 a</td>
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In addition to obvious symptoms on growing points and leaves at higher rates, dicamba causes pollen sterility for an extended period after application.
Dicamba effect on cotton lint yield at various rates and growth stages.

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Nozzles – only allowed to use nozzles on label or listed on web site

- Enlist Duo nozzle table

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Nozzles – Monsanto (2/13/2017), Engenia similar www.xtendimaxapplicationrequirements.com

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</table>

Updated on 4/27/2017 to add John Deere nozzles and more Wilger nozzles
Pre-orifice Air Induction Nozzles:

- TeeJet AI11004
- Air intake venturi section
- Mixing Chamber - air and spray solution blended
- Exit orifice - Pattern tip - forms large air-bubble drops
- Reduced Drift
**TTI Turbo Teejet Induction**

- **Air induction nozzles at moderate pressure** (e.g., 40 PSI)
  - large spray droplets
- **More air-filled droplets**
  - better coverage than solid water droplets

---

**GreenLeaf TDXL-D**

- Modular Versatility.
  - Tip/Cap Setup
  - Gasket/Diffuser
  - TurboDrop® Venturi

*One TurboDrop Venturi, any pattern or spray category you need.*
Nozzles – only allowed to use nozzles on label or listed on web site

AIXR-11004

TDXL-D11006

TADF-D11006

EnlistDuo only

Engenia
Xtendimax

Xtendimax only
Important Droplet Statistics

Operational Area

VMD (50%)

VDO.1 (10%)

VDO.9 (90%)
1/2 of spray volume = smaller droplets

1/2 of spray volume = larger droplets
## Spray Quality Categories

ASABE Standard S-572.1

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<tr>
<th>Category (symbol)</th>
<th>Color Code</th>
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### AIXR TeeJet® (AIXR)

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### Turbo TeeJet® Induction (TTI)

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### AI TeeJet® (AI)

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</tbody>
</table>
Concerns: Off-target movement

- Volatility
  - Formulation technology is effective

- Spray droplet drift – Nozzle technology
  - Apparent differences in spray drift usually due to differential susceptibility of cotton to dicamba and 2,4-D.

- Avoid application to the wrong field!

- Boom height and sprayer speed

- Wind speed and temperature inversions
Boom height

- The higher the boom is above the crop or target, the greater the potential for wind to move droplets-off target.
- Maintain consistent boom height when spraying.
- Follow nozzle manufacturer directions for best coverage
  - Including boom height, pressure and nozzle spacing.
- DO NOT exceed a boom height of 24 inches above target/crop.

<table>
<thead>
<tr>
<th>Droplet Size</th>
<th>Distance by Boom Height</th>
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</thead>
<tbody>
<tr>
<td>Microns</td>
<td>Boom Ht. 20”</td>
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<tr>
<td>&gt; 622</td>
<td>50 ft.</td>
</tr>
<tr>
<td>428-622</td>
<td>69 ft.</td>
</tr>
<tr>
<td>349-428</td>
<td>108 ft.</td>
</tr>
<tr>
<td>177-218</td>
<td>358 ft.</td>
</tr>
</tbody>
</table>

Source: Spray drift modeling data from Monsanto field studies; estimated visual response ratings at 10 mph wind. For illustrative purposes only.
Sprayer Speed

• Enlist Duo
  – Not specified.

• Engenia
  – Select a ground speed that will deliver the desired spray volume while maintaining the desired spray pressure,
  – But DO NOT exceed 15 MPH.

• Xtendimax
  – Select a ground speed that will deliver the desired spray volume while maintaining the desired spray pressure,
  – But DO NOT exceed 15 MPH.
Wind Speed & Temperature Inversions

• Do not apply Enlist Duo, Engenia or Xtendimax during a temperature inversion (see label language).

• Enlist Duo
  – Do not apply at wind speeds greater than 15 MPH.

• Engenia and XtendiMax

<table>
<thead>
<tr>
<th>Wind Speed</th>
<th>Application conditions and restrictions</th>
</tr>
</thead>
</table>
| <3 mph     | Engenia: apply only if a temperature inversion does not exist  
             | XtendiMax: DO NOT apply                  |
| 3-10 mph   | Optimum application conditions          |
| >10-15 mph | Do not apply product when wind is blowing toward non-target sensitive crops. |
| >15 mph    | DO NOT apply                            |
Concerns: Off-target movement

- Volatility
- Spray droplet drift – Nozzle technology
- Boom height and sprayer speed
- Wind speed and temperature inversions
- Buffer requirements
**Downwind Buffer (endangered species):**
Measure wind speed & direction prior to starting any swath within the buffer distance of a sensitive area.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Buffer Distance (ft)</th>
<th>Rate (lb ae/A)</th>
<th>Maintain a downwind buffer (in the direction in which the wind is blowing) from any area except:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enlist Duo</td>
<td>30</td>
<td>0.95</td>
<td>1. Roads, paved or gravel surfaces</td>
</tr>
<tr>
<td>Engenia</td>
<td>110</td>
<td>0.5</td>
<td>2. Planted agricultural fields. (Except those crops listed in the “susceptible Plants” section).</td>
</tr>
<tr>
<td>XtendiMax</td>
<td>110</td>
<td>0.5</td>
<td>3. Agricultural fields that have been prepared for planting (dirt).</td>
</tr>
<tr>
<td></td>
<td>220</td>
<td>1</td>
<td>4. Areas covered by the footprint of a building, shade house, greenhouse, silo, feed crib, or other man made structure with walls or roof.</td>
</tr>
</tbody>
</table>
Acceptable Downwind Crops

- **Enlist Duo**
  - Any crop that is not listed in susceptible plants section

- **Engenia**
  - asparagus, corn, DT cotton, DT soybeans, sorghum, proso millet, small grains and sugarcane. (Crops not listed in the “susceptible Plants” section)

- **XtendiMax**
  - corn, DT cotton, DT soybeans, sorghum, proso millet, small grains and sugarcane. (Applicator must confirm crops are dicamba tolerant.)
Sensitive Plants/Crops – Enlist Duo

• Before making an application, please refer to your state’s sensitive crop registry (if available) to identify any commercial specialty or certified organic crops that may be located nearby.

• At the time of application, the wind cannot be blowing toward adjacent commercially grown
  – tomatoes and other fruiting vegetables (EPA crop group 8),
  – cucurbits (EPA crop group 9),
  – grapes and
  – Cotton.
Sensitive Plants/Crops - Engenia

• DO NOT apply when wind is blowing in the direction of neighboring specialty crops.

• Specialty crops include, but are not limited to:
  – Tomatoes and other fruiting vegetables (EPA Crop Group 8)
  – cucurbits (EPA crop group 9),
  – Peas, potato, tobacco, flowers, fruit trees, grapes, ornaments, including greenhouse and shade house grown broadleaf plants.

• AVOIDING SPRAY DRIFT AT THE APPLICATION SITE IS THE RESPONSIBILITY OF THE APPLICATOR.
Sensitive Plants/Crops - XtendiMax

- Do not allow contact of herbicide with foliage, green stems, exposed non-woody roots of crops, and desirable plants, including beans, cotton, flowers, fruit trees, grapes, ornamentals, peas, potato, soybean, sunflower, tobacco, tomato and other broadleaf plants because severe injury or destruction may result, including plants in a greenhouse.

- DO NOT APPLY this product when the wind is blowing towards adjacent commercially grown dicamba sensitive crops, including but not limited to,
  - tomatoes and other fruiting vegetables (EPA crop group 8),
  - cucurbits (EPA crop group 9), and
  - grapes.
Concerns: Off-target movement

- Volatility
- Spray droplet drift – Nozzle technology
- Boom height and sprayer speed
- Wind speed and temperature inversions
- Buffer requirements
- Residues in spray equipment
Concerns: Sprayer Cleanout
Triple rinse procedure for all – example Enlist Duo

- Drain the sprayer (including boom and lines) completely.
- Do not allow spray solution to remain in system overnight.
- Fill to 10% volume, circulate 15 min, spray out boom.
- Drain system (including lines and booms), remove and clean all strainers, screens and filters.
- Fill tank, use a commercial cleaner containing strong detergents.
- Wash all parts of the tank, including the inside top surface – 15 minutes. Let stand several hours or overnight.

- Spray solution out of tank through boom. Drain system including lines and boom.
- Fill to 10% volume, circulate to contact all internal surfaces – 15 min.
- Spray solution out of tank through boom.
- Completely drain spray system including pump.
- Remove nozzle tips, strainers, filters and clean them separately.
- Also
  - Clean and rinse exterior of sprayer
  - Dispose of all rinsate in compliance with local, state, and federal requirements
Concerns: Off-target movement

- Volatility
- Spray droplet drift – Nozzle technology
- Boom height and sprayer speed
- Wind speed and temperature inversions
- Buffer requirements
- Residues in spray equipment
  - Purdue Extension PPP-108: “Removing Herbicide Residues from Agricultural Application Equipment”
- Misapplication
Tank Mixing

• Growth regulator herbicides may only be tank-mixed with products that have been tested and found by the EPA not have an unreasonable adverse affect on the spray drift properties of the herbicide.

• **Example:** DO NOT tank mix any product with Engenia or XtendiMax unless:
  
  – 1. You check the list of EPA approved products at [www.xtendimaxapplicationrequirements.com](http://www.xtendimaxapplicationrequirements.com) or [www.engeniatankmix.com](http://www.engeniatankmix.com) or no more than 7 days before applying Engenia; and
  
  – The intended tank-mix product is identified on the list of tested products; and
  
  – 3. The intended products are not prohibited on either this supplemental label or the label of the tank mix product.
Approved AZ Cotton Herbicide Tank-mix Partners (5-9-2017) – Must use Drift Reduction Adjuvants with some herbicides

<table>
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<tr>
<th>Engenia</th>
<th>Xtendimax</th>
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<tbody>
<tr>
<td>Roundup PowerMAX, RPMAX II, Roundup WeatherMAX (glyphosate)</td>
<td>Roundup PowerMAX, RPMAX II, Roundup WeatherMAX (glyphosate)</td>
</tr>
<tr>
<td>Bucaneer, Cornerstone, Makaze, Envy Intense, Glyfos X-Tra, Glystar Plus, Envy Intense, Tomahawk (glyphosate)</td>
<td>Honcho K6 (glyphosate)</td>
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<tr>
<td>Prowl H₂O (pendimethalin)</td>
<td>Prowl H₂O (pendimethalin)</td>
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<tr>
<td>Direx (prometryn)</td>
<td>Direx (diuron)</td>
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<tr>
<td>SelectMax (clethodim)</td>
<td>Select MAX (clethodim)</td>
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<tr>
<td>Staple LX (pyrithiobac-sodium)</td>
<td>Warrant (acetochlcor)</td>
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<tr>
<td>Warrant (acetochlcor)</td>
<td>Warrant (acetochlcor)</td>
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</table>
Product Stewardship - Companies

- Promote management practices for herbicide resistant weeds on labels & educational materials
- Collect reports of non-performance of product
- Survey seed purchasers regarding escapes, drift problems, failure to observe buffers, and herbicide resistant weeds annually and report to EPA
- Label expirations:
  - Enlist Duo (Dow): January 12, 2022
  - Engenia (BASF): December 20, 2018
  - XtendiMax (Monsanto): November 9, 2018
Product Stewardship - Growers

• 34 weed species are currently resistant to synthetic auxin herbicides (8 in USA).

• Implement diversified weed control practices
  – Herbicide diversity
    – Broad spectrum soil-applied herbicides as a foundation
    – Sequential applications with alternative sites of action
      – Tank-mixes
    – No more than 2 appl. of group 4 herbicides (dicamba, 4,2-D)
    – Use non-chemical practices – tillage, crop rotation, etc.
  – Sanitation
    – Scout for escapes, No Seed Threshold to stop seed production
    – Field edges, field margins, fence rows, ditches, farmstead weed control to reduce seed production
    – Cleaning equipment, especially harvest equipment
• Zero tolerance for Palmer amaranth flower (pollen) and seed production = SANITATION!

• Remove weeds before they produce viable seed.
Proactive Management Uses a Diversity of Tactics to delay the development of herbicide resistance:

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Mechanical</th>
<th>Cultural</th>
<th>Biological</th>
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<tr>
<td>Multiple herbicides each with different mechanisms of action</td>
<td>Tillage</td>
<td>Crop rotation</td>
<td>Optimum Crop Growth</td>
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<tr>
<td></td>
<td>– Mixes</td>
<td>– Pre-plant</td>
<td>– Crop Competition</td>
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<td>– Sequences?</td>
<td>– In-crop cultivation</td>
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<td>– Across seasons</td>
<td>– Mowing</td>
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<td>– In-row weeding</td>
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<td>– Post-harvest</td>
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<td>Hand-rogueing before seed set</td>
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<td>Sanitation</td>
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<td>– Clean equipment</td>
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<td>– Problem of manure</td>
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More herbicide use, Higher cost, Using herbicides alone, regardless of how we use them will inevitably result in herbicide resistant weeds.
The Problem

• “Widespread, rapid evolution of herbicide-resistant (HR) weeds is destabilizing weed management in commercial agriculture. This problem has reached epidemic levels, driving up crop production costs, decreasing farm profitability, and forcing farmers out of business in some cases.”
New Chemistry for Cotton Weeds in 2017

- Herbicide Resistant Weeds
- New Herbicides
- Herbicide Resistant Weeds in Arizona

Glyphosate resistant Palmer amaranth in Buckeye, AZ cotton field - 2012
Glyphosate resistant Palmer amaranth in Arizona

- Parker - alfalfa
  - field study
- Buckeye - cotton
  - GH: Roundup & Raptor, Staple)
- Coolidge – cotton
  - field spray
- Red Rock - pecans
  - field spray
- Marana - cotton
  - field spray
- Pearce –corn, cotton
  - field spray
- San Simon - pecans
  - field spray
  Also hairy fleabane
Glyphosate Resistant Palmer amaranth
Coolidge – August 24, 2016
1) Sprayed 3 times with Roundup 44 fl. oz./A

2) Sprayed with Liberty (glufosinate) @ >43 fl. oz./A when Palmer was taller than the cotton
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2) Sprayed with Liberty (glufosinate) @ >43 fl. oz./A when Palmer was taller than the cotton

3) Necrotic shoot tips but resprouting

4) Glufosinate (Liberty, Rely) should be sprayed on small plants. Rate is 3.5 to 5 pt./A in pecans
Glyphosate resistant Palmer amaranth in Arizona

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- Buckeye - cotton
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  – field spray
- Pearce –corn, cotton
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- San Simon - pecans
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Glyphosate Resistant Palmer Amaranth in Marana
Cochise County center pivot (2014)
RR corn, post-season tillage & monsoon rainfall
Sprayed with glyphosate
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