Drought Breeding in the Midwest

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- Soybeans subjected to water stress every year somewhere in U.S.
- Drought stress occurs mainly during flowering and pod-fill (July, August, September).
- However time of stress and severity of stress varies considerably.
- As a result a considerable portion of year to year variation in yield is associated with rainfall.

Drought

- "A complex and poorly understood phenomenon that affects more people than any other natural disaster." (Wilhite, 1993)
- A sustained period of time without significant rainfall. (Linsley et al., 1959)
- When such a shortage of rainfall begins to limit plant growth and development (Quizenberry, 1982)

Responses to Drought

- Yield Reduction
  - By affecting characteristics associated with yield

- Morphological Responses
  - Reduction in leaf water potential, loss of turgor
    (Pandey et al., 1984)
  - Increase in canopy-air temperature differences
    (Boyer, 1970, Brady et al., 1975)
  - Leaf orientation, leaf loss
    (Meyer and Walker, 1981; Kramer, 1980)
  - Increase in lipids
    (Clark and Levitt, 1956; Myers et al., 1986)

Responses to Drought

- Morphological Responses (cont'd)
  - Reduction in stem length

    (Bouslama and Schapaugh, 1984)
  - Variation in growth rates and depth of rooting

    (Taylor et al., 1978)
- Physiological Responses
  - Altering of stomatal behavior
  - Osmotic adjustment

Responses to Drought

- Biochemical Responses
  - Decrease in nitrogenase activity

    (Albrecht et al., 1984)
  - Petiole Ureide concentration
  - Changes in hormone concentrations
    - ABA
    - Cytokinin
    - Ethylene
- Type and degree of response dependent on the timing and severity of drought

What does Drought look like in the field?

Screening for Tolerance

- Select for high yield in ideal environments
- Select for high yield under stress conditions
  - Selections specific to stress environments
- Select for low reduction of yield under stress conditions relative to ideal conditions
  - Assumes yield and drought tolerance are separate, heritable characters

Drought Research Activities - MN

- Screening of PI's for drought tolerance.
- Rescreening of PI's and lines.
- Drought tolerance of selected commercial cultivars.
- Study of crosses with southern material.

Our Experience

- Begin when some (20 - 30%) of plants show wilting during warmest time of the day.
- Take ratings when differences are most apparent - from about 10:00 am to 2:00 pm.
- Observe all plots from same perspective.
- Avoid rating when winds strong or in gusts.
- Rate every 3-5 days.

Canopy Wilting Rating Scale

0 - no wilting

1 - slight wilting-wilting on a few plants

2 - some wilting-half or more of plants wilted

3 - significant wilting-most plants wilted

4 - severe wilting-leaf scorching or firing on many plants

5 - completely wilted-yellow, brown or dead leaves on many plants

Screening PI's

- 150 PI's screened under dry land conditions.
- Wilting scores and yield:
  - Yields very low (700 kg/ha)
  - Four wilting scores taken
- Large range of materials
- Best PI's were rescreened in irrigated and non-irrigated.
- Some PI's of interest:
  - PI 612717, PI 593939, PI 578507, PI 578428A, PI 612713A, PI 578474

Rescreening of PI's

- Lines grown dry land and under irrigation.
- Maturities similar in both environments.
- Dry land yields very low (700 kg/ha) irrigated 3080 kg/ha
- Several lines had above average yields and low wilting scores:

  PI 437285, PI 464923, PI 184044, PI 248399
- Protein higher in dryland 38.4% vs 37.7%

  Oil lower in dryland 16.6% vs 18.0%

Midwest Breeding Efforts

- Elite cultivars from maturity group O and I were crossed with drought tolerant southern material derived from PI 416937, PI 471938, and NTCPR94-5157
- Segregants that matured in Minnesota and Nebraska were selected.
- Wilting scores were taken.
- In MN yield trials lines with high yield and low wilting scores compared to checks were identified.

Crosses with Southern Material (Thesis Study)

- PI 471938 x MN0302 (Nepal)
  N94-7784 x MN0302 (Egypt)
  NTCPR94-5157 x MN0302 (US)
  M96-6809 x MN0302 (China, PI416937)

- 66 lines/population, 3 reps
  Irrigated and non-irrigated Becker
  Non-irrigated Rosemount
  Wilting scores: 5 times Becker, 3 times Rosemount

Observations

- Lines blocked by maturity (range mid 0 - late II).
- In general (within maturities) lines showed similar responses at Becker and Rosemount for wilting (range 0.56 - 0.89).
- 5 - 10% of lines were among the best in all three environments.

Trait Evaluation

- Lines matured over approximately 5 weeks
- Significant ($p<.05$) correlations were observed between traits and maturity date
- Lines were grouped by maturity dates into 5 maturity classes, and analyses were done within these maturity classes
- Lines observed as a significant ($p<.05$) source of variation for yield, RYR, wilt score, and height

Wilting

- Significant correlations of Becker wilt scores with RYR at Becker

	Maturity Class				
	1	2	3	4	5
Date 1	.825	.517*	.314*	.258*	.081
Date 2	.914*	.624*	.418*	.122	.006
Date 3	.878*	.611*	.408*	.226*	.131
Date 4	.683	.509*	.642*	.172	.080
Date 5	.920*	.111	.516**	.285*	.017
Date Avg.	.890*	.611*	.488*	.257*	.082

*,** Indicates significance at *p*=.05, and highly significant, respectively

Cross Evaluation

- Erratic nature of drought in MN dictates that crosses be evaluated on the basis of yield as well as RYR
- Crosses observed as significant sources of variation for yield at all environments except one, and for RYR at Becker (p=.05)
- Analysis of wilting scores did not find crosses to be a significant source of variation (p=.05)

Protein and Oil

- Environment significant ($p<.01$) for protein and for oil
- Protein higher and oil lower under stress
- Environment non significant for total protein + oil
- Lines significant for all three traits ($p<.01$)
- No correlations with drought tolerance traits

Conclusions

- Wilting should be a useful indicator of drought tolerance. Need multiple environments
- Plant height doubtful, but needs more testing
- Cross 2 exhibited most tolerance

  Crosses 1 & 3 may be useful

  Cross 4 showed least tolerance

2010 Becker and Rosemount

LINE	PEDIGREE	WILTING SCORE	YIELD
M05-243040	MN1003SP x PI 578425	1.5	34.3
M05-242024	Parker x PI 592960	1.5	31.8
M06-358091	PI 437161 x M94-275024	1.5	28.9
Hendricks	M74-349 x M77-210	2.5	27.9
M06-358117	PI 437161 x M94-275024	1.5	27.5
Sheyenne	P9071 x A96 492041	3.0	25.1

2010 Becker and Lamberton

LINE	PEDIGREE	WILTING SCORE	YIELD
MTC00-112-412	N94-7784 x MN0302	1.5	46.1
M05-243012	MN1003SP x PI 578425	1.5	44.7
M05-248003	MT600-113-54 x MN1003SP	1.5	43.9
Sheyenne	P9071 x M77-210	3.0	43.9
Hendricks	M74-249 x M77-210	2.5	38.7
M05-248081	MTC00-113-54 x MN1003SP	1.0	37.1

2010 Preliminary Tests

Test 1: 9 of 20 wilting score 1.5 or better

best checks – 2.5 Hendricks

– 3.0 Sheyenne

6 of 9 better in yield than Sheyenne

Test 2: 17 of 44 wilting score 1.5 or better

best checks – 2.5 Hendricks

– 3.5 MN1410

7 of 17 better yield than MN1410

Final Comments

- Selection for genotypes with low wilting scores effective
- Crossing with Southern low wilting types successful in transferring Trait.
- Breeding lines with low wilting scores and competitive yield are promising

Thank You!