Establishment and management of switchgrass as a bioenergy crop

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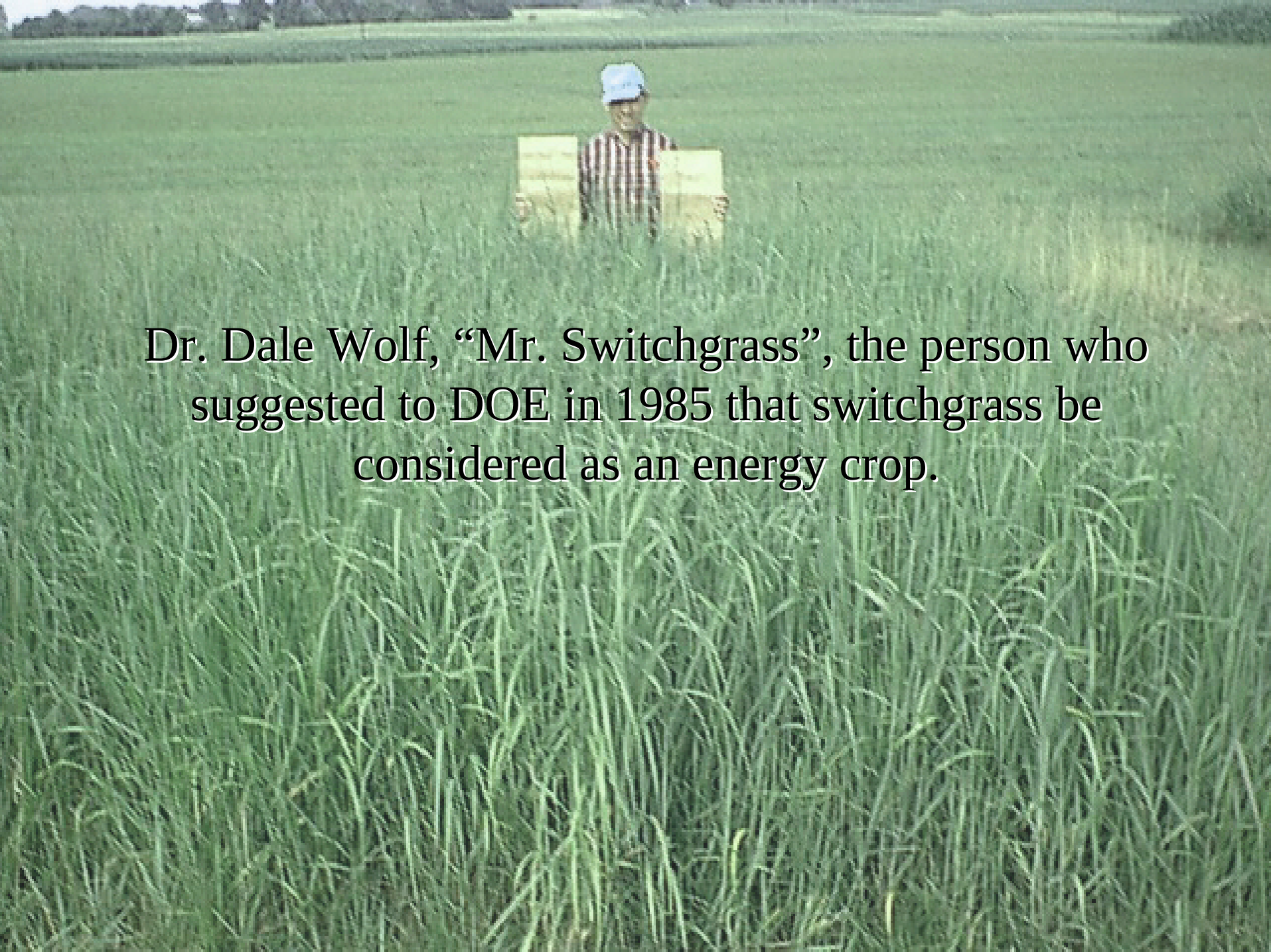
Outline

- Why switchgrass?
- Choosing the right switchgrass
- Success in establishment
- Harvest management
- Fertilization and fertility management
- Words of caution
- Conclusions

Why switchgrass?

- native (not invasive/weedy)
- warm-season grass (heat and drought tolerant)
- perennial (plant it once)
- productive (6 to 7+ tons/ac/yr)
- low fertilization requirements (~50 lb N/ac/yr)
- soil conservation/improvement (1+ ton OM/ac/yr)
- wildlife habitat
- conversion technologies being developed
  - "lignocellulosic biomass" ⇒ ethanol and biodiesel
  - can be co-fired with coal
- well-studied (15 years of DOE-funded work)



Dr. Dale Wolf, “Mr. Switchgrass”, the person who suggested to DOE in 1985 that switchgrass be considered as an energy crop.

Choosing the right switchgrass

- two types/forms of switchgrass
  - upland -- shorter, finer; generally of more northern origin
  - lowland -- often more bunch-like and more productive
- producer's goal: pick a type suited to location/climate
- local, naturally occurring lines often become named cultivars
- most named cultivars are upland types
  - oldest, best known: Cave-in-Rock
- two common lowlands: Alamo and Kanlow
  - Alamo can have problems when planted too far north
- rule-of-thumb: plant lowlands in South, uplands in North

Success in establishment

- switchgrass' reputation: difficult or slow to establish
  - success rate can be high, if Mother Nature cooperates
  - modest harvests (≤ 3 tons/ac) possible at end of first year
  - full productivity can be achieved by second year
- when planting (preferably no-till), pay attention to
  - planting date (soil temperature)
  - weed control
  - seed placement/depth
  - seed quality/dormancy

Increasing the odds for success

- plant after soil is warm (~80 to 85° F) (late May or June)
- control weeds (the Dale Wolf "recipe")
  - apply glyphosate (1 to 2 qt/ac) 4 to 5 weeks ahead
  - remove excessive dead vegetation before planting, if enough present to interfere with no-till seed placement
    - burn if safe and legal
  - apply glyphosate again, if needed, at planting
    - atrazine at low rates (1 lb/ac) may be helpful
  - follow-up broadleaf-weed control as needed
- place seeds $^{1}/_{2}$" to $^{3}/_{4}$" deep (with good slit closure)
- use good, non-dormant seeds

Keys to good seeds

- seed **dormancy** often a major problem
- seed tag info can be quite misleading
  - “% germ” based on a test that breaks dormancy
- seed dormancy can be broken by farmer before planting
  - hold seed for year or two
    - aided by storage at warmer temps
  - wet-chill (practical for 100 to 200 lb of seeds)
    - put **wet** seeds in refrigerator for 4 to 6 weeks
    - remove and dry quickly (or they will germinate)
- with good, non-dormant seeds, 2 to 3 lb/ac is enough

Harvest management

- harvest once or twice per season (no more!)
  - no yield advantage to two cuttings with some types/lines
  - harvest window in June/July (for a two-cut system)
  - fall cutting should come after tops die back (late October)
    - ~10% yield reduction between August and October as materials move out of tops into crowns and roots
    - allows N to be conserved/“recycled” within plants
- delayed/winter harvests are possible
  - generally small monthly yield reductions from October through March

Switchgrass plots being harvested in November after tops have died back and many N-rich materials have moved belowground. (Knoxville, TN)

Switchgrass plots at time of a mid-summer harvest (Princeton, KY)

Spring growth of switchgrass harvested fall-only in previous years. Compare to slide 4 where plots were harvested summer and fall.

Some yield data from a 10-yr study

- eight sites in upper Southeast (KY, NC, TN, VA, WV)
- six varieties/lines planted in 1992
  - four lowland types
    - including Alamo and Kanlow
  - two upland types
    - Cave-in-Rock and Shelter
- two harvest systems/patterns
  - once per year (October)
    - 50 lb N/ac/yr
  - twice per year (June and October)
    - 100 lb N/ac/yr

Seasonal yields from six switchgrass lines from 1994 to 1999 when harvested twice. Data averaged over eight sites.

Treatment		**Year**							
Cuttings	Cultivar	1993	1994	1995	1996	1997	1998	1999	**Mean**
		----------Mg ha^{-1}----------							
Two	Alamo	12.3	15.2	17.3	16.5	12.2	17.7	15.1	**15.7**
	Cave-in-Rock	11.8	15.6	15.0	15.5	12.2	17.8	14.8	**15.2**
	Kanlow	13.1	15.8	17.3	16.0	12.1	18.4	14.2	**15.7**
	NC1	13.6	15.2	18.2	16.2	12.0	18.3	14.7	**15.9**
	NC2	13.1	14.3	17.0	15.9	11.8	18.4	14.4	**15.4**
	Shelter	10.5	13.5	14.0	13.2	10.6	16.0	12.6	**13.4**
	Mean	**12.3**	**14.9**	**16.5**	**15.5**	**11.8**	**17.8**	**14.3**	**15.2**

11 Mg/ha = 4.9 tons/ac
13 Mg/ha = 5.8 tons/ac
15 Mg/ha = 6.7 tons/ac
17 Mg/ha = 7.6 tons/ac

Seasonal yields from six switchgrass lines at eight sites when harvested once or twice per year. Data averaged over six years (1994 to 1999).

Treatment		Virginia			Tennessee					
		Blacksburg								
Cuttings	Line	Site A	Site B	Orange	Knox.	Jack.	NC	KY	WV	**Mean**
		---Mg ha^{-1}---								
One	Alamo	12.3	13.6	16.6	20.7	12.3	15.2	14.3	15.5	**15.1**
	CIR	11.9	12.0	10.2	16.0	10.3	9.8	12.2	12.7	**11.9**
	Kanlow	13.6	16.2	13.5	20.0	12.3	15.1	15.3	17.4	**15.5**
	NC1	13.7	16.2	15.0	19.0	12.4	15.2	13.9	-	**15.2**
	NC2	12.0	14.7	14.8	20.1	11.3	16.9	14.9	-	**15.1**
	Shelter	10.7	10.8	9.7	14.0	9.8	9.2	10.7	11.3	**10.7**
	Mean	**12.3**	**13.9**	**13.3**	**18.4**	**11.4**	**13.5**	**13.6**	**14.6**	**13.9**
Two	Alamo	14.3	18.9	14.6	19.4	12.5	17.1	15.7	13.0	**15.7**
	CIR	15.8	18.0	13.3	19.6	13.0	15.1	13.5	13.0	**15.2**
	Kanlow	15.5	17.7	14.2	18.5	13.3	17.9	14.7	13.4	**15.7**
	NC1	15.0	20.2	15.4	18.6	12.4	18.3	13.3	-	**15.9**
	NC2	15.4	18.1	14.9	18.1	13.7	16.2	13.8	-	**15.4**
	Shelter	13.9	15.8	10.7	19.0	12.0	13.1	10.8	11.6	**13.4**
	Mean	**15.0**	**18.1**	**13.8**	**18.9**	**12.8**	**16.3**	**13.6**	**12.8**	**15.2**

13 Mg/ha = 5.8 T/ac 16 Mg/ha = 7.2 T/ac 19 Mg/ha = 8.5 T/ac

Fertilization and nutrient management

- switchgrass seldom responds to additions of P or K (or sometimes N)
  - soil nutrient levels generally considered low for corn may be quite adequate for switchgrass
- farmer's goal: replace nutrients being removed in biomass harvests
  - maintain nutrients at levels that will provide good yields
  - more nutrients are being removed (and must be replaced) with two harvests per year

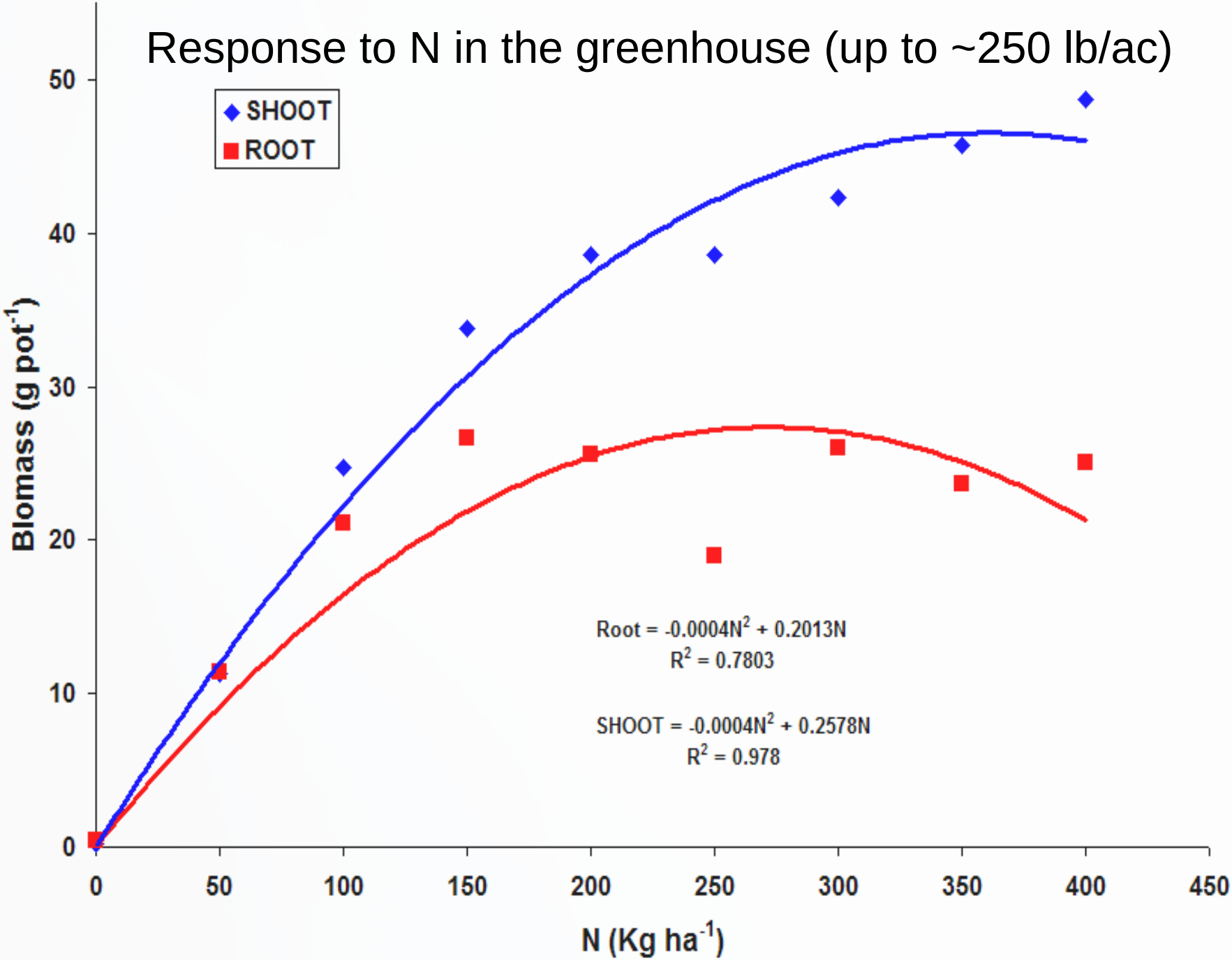
Nutrients in Alamo switchgrass sampled in June and November under one- and two-cut management. Averages for eight sites 1997 thru 1999.

Variable	Nutrient	One cutting	Two cuttings		
		Nov.	June	Nov.	Total
		----------%	----------		
Tissue concen-tration	**N**	**0.48**	**0.97**	**0.65**	**-**
	P	0.10	0.18	0.12	-
	K	0.56	1.27	0.65	-
	Ca	0.32	0.28	0.39	-
		----------kg ha^{-1}	----------		
Removed In the harvested biomass	**N**	**66.2**	**66.6**	**63.3**	**129.9**
	P	12.6	11.7	10.6	22.2
	K	78.0	86.1	65.8	151.9
	Ca	44.9	30.4	36.8	67.2

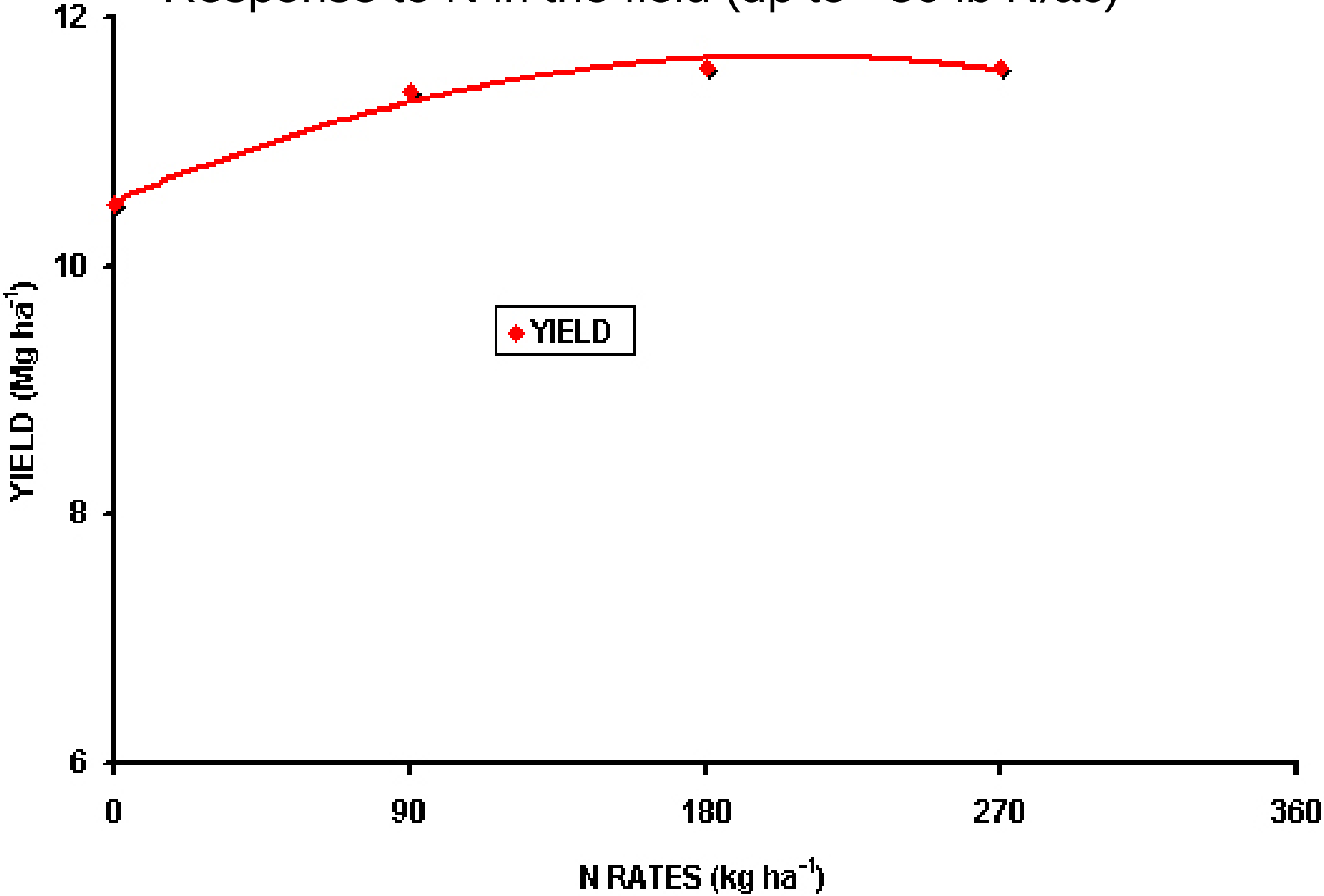
Keys to N management

- fairly low levels of applied N can produce high yields
  - with a single, end-of-season cutting:
    - 50 lbs N/ac maintains high productivity
    - almost enough N falling out of sky!
  - more N needed if also making mid-summer harvests
    - 100 lb N/ac appears sufficient to maintain yields
- switchgrass can “recycle” its N at the end of the season
  - harvesting after tops die back reduces N requirements
- too much N can cause lodging (and reduce yields)

Response to N in the greenhouse (up to ~250 lb/ac)



Response to N in the field (up to ~50 lb N/ac)



Words of caution…

- current “craze” built largely on ethanol from corn
  - not on “lignocellulosic” ethanol or biodiesel
- conversion technologies for lignocellulosics still being developed
- “biorefineries” are being built (but not yet proven)
- major logi$tical issues in getting biomass from farm gate to biorefineries
- bioenergy not “the” solution
  - but it can be part of the solution

Conclusions

- Switchgrass is a very promising energy crop candidate
- Lowland cultivars generally out-produce uplands in warmer, longer-season areas
- No-till establishment can work with proper attention given to timing, weed control, and seed dormancy
- Cut 1 time/yr (after die-back) or no more than 2 times/yr
- 50 lb N/ac/yr adequate with one-cut management
    - increase to 100 lb/ac with two cuttings/yr
- With good management, switchgrass stands can be truly perennial, essentially “permanent”