GINNING EFFICIENCY IN UPLAND COTTON – RESEARCH PROGRESS

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Abstract

In the past few years, there has been a consorted effort between cotton geneticists/breeders, ginning engineers and molecular scientists to understand 'ginning efficiency' in upland cotton. Ginning efficiency includes ginning rate (measured in g lint sec^{-1}) and net gin stand energy (measured in Wh kg^{-1} lint). Improved ginning efficiency incorporates both reduced net gin stand energy usage (that above idling) and increased ginning rate. Tests for ginning efficiency have indicated that significant differences existed between cultivars for these traits. These differences were attributed to fiber-seed attachment forces. Cultivars with lower attachment forces consumed the least amount of net gin stand energy. It was also found that ginning rates were consistently negatively correlated with fuzz percent and positively correlated with net gin stand energy. Fuzz percent also had higher heritability and higher genetic advances from selection when compared to ginning rate and net gin stand energy. It is also faster and cheaper to measure and therefore can be used as a selection criteria for ginning efficiency by cotton breeders. So far, enough ginning and genetic information has been collected to enable cotton breeders to include ginning efficiency as a value-added trait in cotton improvement. Molecular studies to identify QTL associated with ginning rate and net gin stand energy is underway.

Introduction

In the history of cotton breeding, improvement of ginning efficiency was an early target. Ware in 1951 suggested the utilization of black-seeded genotypes to improve ginning efficiency. Gins today are looking for every opportunity to improve the bottom line by increasing capacity and efficiency while preserving fiber quality (Valco and Ashley, 2008).

Cotton genotypes differ in how strongly fibers are attached to the seed (Fransen et al, 1984 and Porter and Wahba, 1999). Genotypes with high fiber-seed attachment force tend to reduce gin productivity by increasing power requirements, slowing the system and increasing fiber damage as measured by short fiber contents and neps.

If we select for genotypes with strong fibers loosely attached to the seed we can increase ginning rate, reduce net gin stand energy and reduce unwanted fiber breakage. Research so far has indicated that genetic variability exists for these traits (Anthony et al., 1982; Bechere et al., 2011; Boykin, 2007). So, we can manipulate these into our high yielding, quality cotton cultivars to boost the competitiveness of American cotton in the world market.

Ginning efficiency is improved by increasing the ginning rate and/or reducing ginning energy. The rate of ginning might be increased and the energy required for ginning reduced through breeding for low fiber-seed tenacity.

The overall objective of this project is to investigate the potential for developing a breeding program for improved ginning efficiency – which included both reduced net gin stand energy usage (that above idling) and increased ginning rate. To do this, however, it is essential to do some genetic and molecular investigations to understand these traits.

Geneticists/Breeders

- Check for availability of genetic variability
- Make crosses for
  - Genetic studies.
  - Developing pop. for phenotyping

Ginners

- Test fiber seed attachment forces
- Correlate small sample gin results with commercial gins
- Take ginning rate and net gin stand energy measurements.

Molecular Scientists

- Screen for marker polymorphism.
- Genotype pop. with polymorphic markers.
- Identify QTL associated with ginning rate and gin stand energy.

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Goal

- Develop scientific understanding of ginning rate and gin stand energy.
- Transfer these traits into adapted quality and good yielding cotton cultivars.

Figure 1. The approach to investigating ginning efficiency

Research Progresses on (a) Evaluation of Cotton Genotypes for Ginning Rate and Net Gin Stand Energy (b) Genetics of Ginning Efficiency (c) Fiber-seed attachment forces and (d) Molecular Study are reported.

(a) Evaluation of Cotton Genotypes for Ginning Rate and Net Gin Stand Energy

Methods

- Forty-six conventional and transgenic genotypes were planted in replicated trials at two locations in Stoneville, MS during 2008 and 2009.
- The cotton was ginned in a 10-saw laboratory gin stand to evaluate ginning energy requirements and ginning rates.
- Power consumed by the gin stand was measured and recorded with a Yokogawa power meter.
- Ginning efficiency was based on measurements of gin stand energy (Wh kg^{-1} lint) and ginning rate (g lint s^{-1}).

Figure 2. Yokogawa power meter.

Figure 3. 10-saw laboratory gin stand

Results

The 46 genotypes were classified into 4 distinct groups:

(1) Low net energy, fast ginners
(2) High net energy, fast ginners
(3) Low net energy, slow ginners
(4) High net energy, slow ginners

Fuzz percent was negatively associated with ginning rate but positively associated with net ginning stand energy (Table 1). Fuzz percent was easier, faster, and cheaper to measure.

Table 1. Correlations between ginning rate, net ginning energy and fuzz % in four different crosses

	AR 9317-26 X FM 842ne		JJ 1145ne X Arkot 9608ne		MD 52ne X MD 25		TAM 182-34 ELS X AR 9317-26	
	Gin. Rate	Net gin Energy	Gin. Rate	Net gin Energy	Gin. Rate	Net gin Energy	Gin. Rate	Net gin Energy
Fuzz Percent	-0.68*	0.83**	-0.54*	0.45	-0.23**	0.32**	-0.48**	0.54**
Fiber Length					-0.01	0.36**	0.01	0.34**
Fiber Strength					-0.09*	0.50**	0.05	0.35**
Ginning Rate	---	-0.74*	---	-0.44*	---	-0.08*	---	-0.46**

* Significantly different at P<0.05 in t test.
** Significantly different at P<0.05 in t test.

- Overall genotypes that ginned faster and required less energy to gin had lower nep size, nep count and short fiber content.
- Bechere et al. 2011.

(b) <u>Genetics of Ginning Efficiency</u>

Methods

- Two crosses made by Dr. Meredith (Ark 9317-26 X FiberMax 832ne and JJ 1145ne X Ark 9608ne) were used.
- F_2 from each cross bulked to produce F_3 from which 62 individual plants per population were randomly harvested in 2009 to produce progeny rows.
- The progeny rows were planted in randomized complete block design with two replications at two sites in Stoneville, MS during 2010 and 2012.
- Data was collected on ginning energy requirement, ginning rate and fuzz percent and estimation of broad sense heritability, variance components, genotypic and phenotypic correlations and selection responses were made (Table 2)

Results

Table 2. Heritability and genetic advances for ginning rate, net ginning energy and fuzz % from two crosses

	Ark 9317-26 X FM 832ne			JJ 1145ne X Arkot 9608ne		
	Fuzz %	Ginning rate	Net ginning energy	Fuzz %	Ginning rate	Net ginning energy
Broad sense heritability	0.61	0.16	0.38	0.76	0.15	0.31
Genetic Advance from selection	2.4	0.09	0.71	3.56	0.08	0.35
Bechere et al.,	2014 .					

(c) Fiber-seed attachment forces

Methods

Fiber-seed attachment force was measured with a modified SDL2 Cotton Seed Attachment Tester (Shirley Developments Limited, Didsbury, Manchester, UK). To measure fiber-seed attachment force, a pendulum was raised and locked into position with a known amount of potential energy (Fig. 1). A cartridge was placed in the path of the pendulum, which held the seed in place behind a slotted plate on one side of the pendulum path and the tuft of fibers retained by clamps on the alternate side of the pendulum path . The pendulum was released to pass through the fiber bundle between the seed plate and fiber clamp, thus shearing the tuft of fiber from the seed. The instrument was modified with an inclinometer and computer to measure and record the peak position (angle) of the pendulum swing after shearing ("sample peak position"). Blanks were also run without sample to measure the peak position (angle) of the pendulum blank ("blank peak position"). The difference in the blank peak position and sample peak position was used to calculate the fraction of energy removed from the pendulum swing. This was multiplied by the potential energy of the pendulum to determine the energy required to shear the fiber bundle from the seed. The fiber bundle was weighed, and fiber-seed attachment force (cN*cm/mg fiber) was determined by dividing the energy for shearing the bundle (cN*cm) by the fiber weight (mg fiber).

Figure 1. Fiber-seed attachment force tester just before releasing the pendulum.

Results

- Fiber-seed attachment forces varied statistically among cultivars ranging from 36 cN*cm/mg fiber for Ark 9317-26 (semi-naked seed) to 64 cN*cm/mg fiber for Phy 72.
- Ark 9317-26 consumed the least amount of net gin stand energy and Phy 72 consumed high net gin stand energy (Table 3).

Table 3. Fiber seed attachments, net gin stand energy, ginning rate and fuzz % in some upland cotton cultivars

Cultivars	Fiber-seed attachment force (cN*cm/mg fiber)	Net gin stand energy (Wh kg^{-1} lint)	Ginning rate (g lint s^{-1})	Fuzz %
PHY 72	64.1 a†	11.8	2.72	12.4
TAM 182-34 ELS	56.8 abcd	12.0	3.11	11.3
JJ 1145ne	55.0 abcd	10.3	3.12	12.1
SG 747	53.0 bcde	9.7	3.02	14.7
MD 15 (Okra)	49.5 cde	10.0	3.21	10.6
FM 832 (Okra)	49.4 cdef	10.5	3.15	12.4
DP 555 BR	44.9 ef	9.9	2.96	12.8
SC-9023 - NS (Naked seed)	43.9 ef	9.0	2.89	8.2
AR 9317-26 (Naked seed)	36.1 g	7.5	3.09	6.4
LSD (0.05)		0.4	0.37	1.3

†Numbers followed by similar letters are not significantly different from each other

- Boykin et al., 2012.

(d) Molecular Study

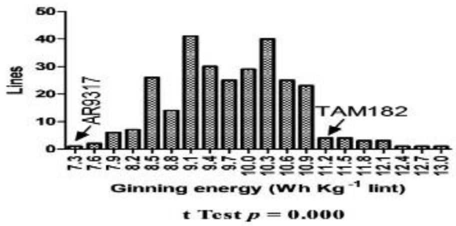
Methods

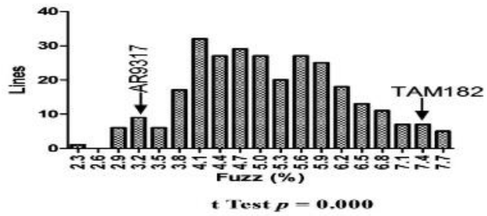
- Two populations were developed for QTL mapping
  1. MD 52ne x MD 25 (For ginning rate. MD 52ne = 2.87 g lint s^{-1} and MD 25 = 3.49 g lint s^{-1})
  2. TAM 182-34 ELS x Ark 9317-26 (For net ginning energy. TAM = 11.2 Wh kg^{-1} lint and Ark 9317-26 = 7.18 Wh kg^{-1} lint)

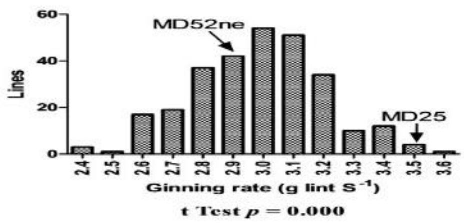
- Leaf samples collected from F_2.
- 288 F_3 progeny rows derived from individual F_1 plant for each cross along with the parents were planted in replicated rows at Stoneville, MS, for phenotyping for ginning rate, gin stand energy, Fuzz percent and quality traits.

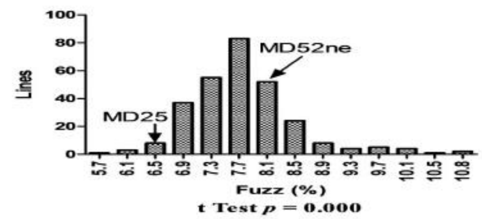
Results

- Currently – The parents are being screened for polymorphism and the populations are being genotyped with polymorphic markers.









Summary

- Enough genetic variability exists for ginning efficiency to warrant an improvement program.
- High heritability and genetic advance was observed when selecting for ginning efficiency.
- Genotypes with lower fiber-seed attachment force requires less energy to gin and also gin faster
- Fuzz % can be used for selecting ginning efficient lines. It is cheaper, easier and faster to measure.

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