J. Plant Breed. Genet. 04 (01) 2016. 01-05

Available Online at ESci Journals
Journal of Plant Breeding and Genetics
ISSN: 2305-297X (Online), 2308-121X (Print)
http://www.escijournals.net/JPBG

DETERMINATION OF THE GENETIC INHERITANCE OF THE OVULE FUZZLESS TRAIT IN *GOSSYPIUM ARBOREUM* GERMPLASM

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A B S T R A C T

The United States Department of Agriculture, National Plant Germplasm System *Gossypium arboreum* collection is an important source of genetic diversity for cotton improvement. Inheritance of the fuzzless trait was determined by crossing PI 615737 x PI 529729 (ovule fuzzy). Seeds from F_1 plants showed ovule fuzz development and the F_2 segregation data fit a single recessive gene model for the fuzzless trait. Additionally, results indicate incomplete dominance for ovule fuzz development. The information generated from the study will aid in further determination of the ovule fuzzless trait inheritance in cotton.

Keywords: Cotton, fiber, germplasm, ovule trichome, naked-seed.

INTRODUCTION

Gossypium arboreum L. (Asiatic cotton) is a diploid cotton species, which was widely cultivated in Asia prior to the introduction of allotetraploid *G. hirsutum* L. (upland cotton) (Guo *et al.*, 2006). Presently, *G. arboreum* varieties are being cultivated in less productive regions not suitable for upland cotton production or under low input management practices. *Gossypium arboreum* is an important source of genetic diversity for drought and salt tolerance, fiber and seed quality traits, and for insect, nematode, and disease resistance (Ma *et al.*, 2008; Mehetre *et al.*, 2003; Yik and Birchfield, 1984). These traits would benefit upland cotton improvement; however, transferring desirable traits from *G. arboreum* to *G. hirsutum* is cumbersome requiring specialized breeding approaches (Gill and Bajaj, 1987; Mehetre *et al.*, 2003; Sacks and Robinson, 2009). Improving the efficiency of introgression can be achieved by determining the inheritance of specific traits of interest (Sacks and Robinson, 2009). Additionally, evaluating the genetic regulatory mechanisms and physiological factors for important traits is simplified in diploid species compared to polyploid relatives (Desai *et al.*, 2008; Wang *et al.*, 2008).

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Cotton fibers grow as single cell trichomes from the epidermal layer of the ovule. Lint and fuzz are the two types of fiber that occur on the cotton ovule. Lint fibers are the economically important fibers used for textile production. These fibers are initiated at anthesis, can elongate up to 30 mm in length, and are generally removed during the ginning process (Stewart, 1975; Turley and Kloth, 2002). In contrast, fuzz fibers are short fibers adhering to the seed coat that can be observed on the seed after ginning (Du *et al.*, 2001). Growth of fuzz fibers is initiated 4 days post anthesis with these fibers elongating to approximately 0.5 mm (Stewart, 1975; Zhang *et al.*, 2007). The ovule fuzzless trait is characterized by a lack of fuzz fiber development on the seed coat. The ginning of fuzzless varieties will generate black seed and has been referred to as the naked-seed phenotype (Ware *et al.*, 1947). The fuzzless trait is an important trait being used to determine physiological factors controlling fiber development (Lee *et al.*, 2006; Wang *et al.*, 2008) and fiber properties (An *et al.*, 2010) in *G. hirsutum*.

Several ovule fuzzless mutations have been reported in *G. arboreum* (Hutchinson, 1935; Rong *et al.*, 2005; Wang *et al.*, 2008), but more information on the genetics of the trait is needed for accessions in the germplasm collection. Accession PI 615737 was identified as a fuzzless cultivar from the United States Department of

Agriculture (USDA), National Plant Germplasm System (NPGS) *G. arboreum* collection. The aim of this investigation is to determine the inheritance of the ovule fuzzless trait. The data from this study will aid in determining the genetic mechanisms controlling fiber development on cotton ovules.

MATERIALS AND METHODS

More than 1,600 *G. arboreum* accessions are maintained in the NPGS collection (https://npgsweb.ars-grin.gov). Accession PI 615737 (A2-236) showed the ovule fuzzless trait (Figure 1) during an evaluation of 300 accessions from the germplasm collection (unpublished data). To determine the inheritance of the fuzzless trait, PI 615737 was used as the female parent and PI 529729 (A2-101) as the pollen parent. Accession PI 529729 shows profuse fuzz development on the seed coat (Figure 1). Accessions PI 615737 and PI 529729 are similar for a number of phenotypic traits including laciniate shaped leaves, red pigmented stems, and flowers with a red petal spot (unpublished data). The two accessions differ for flower color with PI 615737 having a yellow colored corolla and PI 529729 having a white colored corolla. The phenotypic characterization of the parental varieties was based on the standardized cotton descriptors (https://www.cottongen.org/data/trait/NCGC_rating_scale). F_1 seeds were planted in the field and self-pollinated to produce F_2 seed. Seeds for the F_2 population were planted in the field at the USDA in Stoneville, Mississippi on 5 May 2014. The population was planted in a single 150 m row with approximately 0.3 m spacing between plants. Individual plants in the row were tagged at the flowering stage and corolla color was recorded for plants with flowers. The corolla color phenotypes were determined as described by Hutchinson (1931). At maturity, 10 to 20 bolls were harvested from individual plants. The seed cotton from these bolls was ginned using a 10-saw laboratory gin and visually rated for the presence or absence of fuzz fibers on the ovule surface. The fuzzless and fuzzy ovule phenotypes were characterized as described by Ware (1940). The fuzzless phenotype showed a lack of fuzz development on most of the seed surface; whereas, plants classified as fuzzy showed fuzz development across the seed surface. The F_2 plants were classified as either fuzzless or fuzzy and were not classified for the amount or density of fuzz on the seed surface. Segregation ratios for the ovule fuzzless trait and corolla color were tested using the Chi-square test of significance (Statistix 9, Analytical Software, Tallahassee, FL).

Figure 1. Ginned seeds showing the fuzzy and fuzzless ovule phenotypes for the *Gossypium arboreum* accessions used as parents to determine the inheritance of the fuzzless trait (Figure 1). Accession PI 615737 was the ovule fuzzless parent and accession PI 529729 the ovule fuzzy parent with F_1 seeds from the cross PI 615737 x PI 529729 showing less ovule fuzz development compared to PI 529729.

RESULTS AND DISCUSSION

The F_1 plants from the cross PI 615737 x PI 529729 showed fuzz development on the ovules indicating the fuzzless trait was recessive; however, less fuzz was observed on seeds from F_1 plants compared to the PI 529729 parent suggesting incomplete dominance for the present of ovule fuzz (Figure 1). All F_1 plants showed yellow corolla color. The F_2 segregation data for the PI 615737 x PI 529729 population are presented in Table 1. The F_2 segregation data supported a single dominant gene model for yellow corolla color as previously reported by Hutchinson (1931). The ovule fuzzless trait data fit a single recessive gene model. Wang *et al.* (2008) evaluated a fuzzless genotype selected from a Chinese *G. arboreum* landrace, but the inheritance of the fuzzless trait was not reported. This genotype showed the fuzzless trait with some fuzz fibers on the chalazal end of the seed. The *G. arboreum* accession PI 529740 (SMA-4) shows the ovule fuzzless and fiberless traits where no fuzz or lint fibers are produced on the seed; although, Rong *et al.* (2005) indicated F_2 plants were less easily classified due to the appearance of tufts of fiber on the seed. The fuzzless trait for PI 529740 is conferred by a single recessive gene with the fiberless trait epistatic to the fuzzless trait. Rong *et al.* (2005) mapped the PI 529740 fuzzless gene to linkage group A3 in *G. arboreum*, which corresponds to homoeologous chromosomes 6 and 25 in *G. hirsutum*. Hutchinson (1935) reported a dominate gene for the fuzzless trait in a *G. arboreum* landrace from China in which the genotype was characterized as fuzzless expect for small tufts of fuzz fiber on the chalazal and micropylar ends of the seed. Seeds of accession PI 615737 also show tufts of fiber at the micropylar end (Figure 1). For accession PI 615737, the lint fibers strongly adhered to the micropylar end of the seed and were not typically removed during the ginning process.

Table 1. Phenotypic segregation data for 584 F_2 plants derived from the *Gossypium arboreum* cross PI 615737 x PI 529729 used to determine the inheritance of the ovule fuzzless trait in PI 615737.

Trait	Phenotype	Number of Plants	χ^2 (3:1 segregation ratio)	*P*-value
Seed Fiber	Fuzzy	448	0.913	0.3393
	Fuzzless	136		
Corolla Color*	Yellow	274	1.293	0.2555
	White	79		

*Corolla color data were obtained from 353 F_2 plants.

Multiple genes have also been reported for the ovule fuzzless trait in *G. hirsutum*. Ware *et al.* (1947) reported a recessive gene for the fuzzless trait in the genotype ‘Acadian Brown’ with the F_1 seed showing less fuzz indicating incomplete dominance for the fuzzy ovule trait. Variation in the amount of fuzz fibers on the seed coat was observed for the F_2 population in the present study also suggesting incomplete dominance for the fuzzy ovule trait (Figure 2). However, the variation in the amount of fuzz fiber on the seed reported by Ware *et al.* (1947) was not observed for the PI 615737 x PI 529729 F_2 population. Several studies have reported extensive variation in the amount of fuzz fibers on the ovule for segregating populations (Bechere *et al.*, 2012; Ware, 1940; Ware *et al.*, 1947), but no study has evaluated the genetics of this variation. Some of the variation in the amount of fuzz fibers on the ovules for the F_2 population in the present study could be attributed to the variation in ginning efficiency resulting from differences in boll sample size for the plants in the population. Ware (1940) and Ware *et al.* (1947) also reported a dominant gene for the fuzzless trait in two *G. hirsutum* genotypes. Additional studies have confirmed the presence of these two fuzzless genes in *G. hirsutum* (Du *et al.*, 2001; Turley *et al.*, 2007). A third gene for the fuzzless trait in *G. hirsutum* has been identified by Turley and Kloth (2002), which was recessive to the fuzzy ovule trait. The three genes have been designated N_1, n_2, and n_3 with N_1 and n_2 mapping to different positions on chromosome 12 (Kohel, 1973; Narbuth and Kohel, 1990; Rong *et al.*, 2005). Chemical mutagenesis of the *G. hirsutum* cultivar ‘SC 9023’ has resulted in the development of a naked-tufted mutant (Bechere *et al.*, 2012). The ovule fuzzless trait in this mutant line was conferred by a single recessive gene and represents the fourth fuzzless gene identified in *G. hirsutum*. These studies have indicated multiple genes conferring the ovule fuzzless trait in *G. hirsutum* and would suggest the presence of multiple genes for the fuzzless trait in the *G. arboreum* germplasm collection.

The NPGS *G. arboreum* collection is being further evaluated to identify additional fuzzless accessions to determine the diversity of the ovule fuzzless trait in the collection. Additionally, a recombinant inbred population is being developed to genetically map and further characterize the single recessive gene conferring the ovule fuzzless trait in accession PI 615737 to determine if the gene is the same gene as identified in PI 529740 or corresponds to one of the genes identified in *G. hirsutum*. This data will aid in determining the genetic mechanisms of fiber development for cotton improvement.

Figure 2. Phenotypic variation in ovule fuzz development for the F_2 population derived from the *Gossypium arboreum* cross PI 615737 x PI 529729 used to determine the inheritance of the ovule fuzzless trait in accession PI 615737 (Figure 2). Ginned seeds with fuzz fibers covering most of the seed surface were classified as fuzzy. Seeds classified as fuzzless were nearly devoid of fuzz fibers on the seed surface with only the presence of tufts of fiber on the ends of the seed..

ACKNOWLEDGEMENT

This research was funded by the United States Department of Agriculture, Agricultural Research Service project 6066-22000-074-00D. Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the US Department of Agriculture. USDA is an equal opportunity provider and employer.

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