WITHIN-BOLL YIELD COMPONENTS OF HIGH YIELDING EGYPTIAN COTTON GENOTYPES

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Abstract

Cotton yield is integrated through whole-plant and within-boll yield components. Four Egyptian cotton genotypes (Gossypium barbadense L.) were evaluated for within-boll seed yield (boll weight, bolls per plant, and lint percentage) and yield components (seeds per boll, motes per boll, ovules per boll, seed mass, lint mass, and seed-setting efficiency). The question arises that how do within-boll yield components differ from old cultivars to recent isolated hybrids? Two commercially available cotton cultivars and two isolated hybrids were evaluated in years 2010, and 2011. Ten plants were hand-harvested by fruiting position. Five bolls from first- and second-position bolls from the middle of the fruiting zone were hand-harvested. One of the two isolated hybrids (G.90 x Australian) produced more bolls per plant with more seeds per boll. This also resulted in a greater number of ovules produced boll and a lower number of motes per boll with this isolated hybrid. The greater seeds per boll of (G.90 x Australian) was concomitant with greater seed-setting efficiency compared with the other two cultivated cultivars.

Keywords: cotton, within-boll yield component, and old and isolated hybrids.

INTRODUCTION

Cotton farmers are paid according to the total amount of seed cotton and seeds that they produce, thus, producing as much seed cotton and seeds as possible by having high yields is what farmers and breeders aim to do.

Lint cotton yield may be expressed as the function of the production of assimilates by photosynthesis (source), the translocation of assimilates to the developing fibers, and the utilization of assimilates by the fiber cells (sinks). For many crops, the partitioning of assimilates to the harvestable portion is enhanced by high endosperm cell number in developing seeds (Bowman et al., 2001). Cotton differs from other crops in that the harvestable portion is not the seed but rather the lint fibers that are appendages of the seed. The lint fibers originate from fiber cells initiated on the developing ovules at the time of anthesis.

Worley et. al. (1974) concluded that bolls number per unit land area was the largest contributor to lint yield, followed by seeds number per boll and lint mass per seed. Culp and Harrell (1975) reported that increased lint yield was possible under a selection of medium to small bolls with the greatest possible number of small seeds per boll while maintaining a high lint percentage (lint mass relative to seed cotton mass). These authors suggested that more seeds per boll may be desirable because of the greater amount of surface area for lint production within the boll (Harrell and Culp 1976). Miller and Rawlings (1967) also found out, as yield increased by lint percentage, and seeds per boll increased the boll and seed mass decreased.

The primary lint yield components that contribute to lint yield are bolls per unit area, seeds/boll and lint/seed. Lint, seed and seed cotton biomass are closely related to the number of bolls per unit area (Wells and Meredith 1984).

The most commonly used and accepted yield component equation, is the geometric model proposed by Kerr (1966) and is shown as Yield = bolls/unit area x seeds/boll x lint/seed. More recently summarized by (Heitholt, 1999) as Yield = bolls/unit area x lint/boll which are very similar as seeds/boll and lint/seed are the key contributors to boll size.

Simultaneous improvement in multiple yield components provides an opportunity to increase yield using straightforward selection parameters. Cotton fibers are produced on the surface of seed, so an increase in the number of seeds of similar size should lead to an increase in fiber production.

The inheritance of and interrelationships among yield components is of interest to cotton breeders. The contribution to yield of various yield components was reviewed by Heitholt (1999), who noted key contributions from the number of bolls per plant and lint percentage and that both number of bolls per unit land area and seeds per boll was the first largest contributor to lint yield.

Data from recent experiments showed two contemporary cultivars possessed lower boll and seed mass than any found in the cotton literature (Bednarz et. al. 2006). Ragsdale and Smith (2007) found that converted race stocks (CRS) accession M-9044-0162 had the best mean performance for seed per boll (S/B), low motes per boll (M/B), ovules per boll (O/B), and seed setting efficiency (SSE), suggest that it would be a good genotype for improvment within-boll seed yield components in upland cotton.

The questions arise, how are within-boll yield components related to yield in new high yielding Egyptian cotton cultivars? Do these characteristics differ from earlier reports? Are small boll and seed mass a common characteristic of a new high yielding Egyptian cotton cultivars? If it is possible to identify a common within-boll yield components among high yielding genotypes, selection criteria for future cultivar development may identify that capitalize on these most basic yield components. Hence, the objectives of this investigation were to determine how yield components differ from old to new high yielding Egyptian cotton cultivars.

No study has yet determined the potential of recent Egyptian germplasm to improve within-boll seed yield components in elite cotton cultivars. The objective of this investigation was to determine the potentiality to improve within-boll seed yield components by evaluating four Egyptian cotton genotypes.

MATERIALS AND METHODS

Four Egyptian long staple cotton genotypes, two commercial cotton cultivars and two germplasm lines were selected from the breeding program, based on their agronomic performance. The genotypes were as follows: two old cultivated cultivars (G.80 and G.90) and two isolated hybrid genotypes ([(G.75 x 5844) x G.83] x G.80 and (G.90 x Australian.)

These four genotypes were evaluated in single-plant culture, 0.70 by 7.0 m, to minimize interplant competition. Experiments were conducted in 2010 and 2011 in a randomized complete block design with four replications of ten plants each. Common cultural practices for cotton production were kept at optimum levels throughout the growing season to obtain a maximum yield were used at Sids Agri. Exper. Station, ARC.

Seed cotton yield from each ten plants was ginned to determine within-boll seed yield and yield components. Five bolls from first- and second-position bolls from the middle of the fruiting zone were preferentially hand-harvested to minimize effects due to fruiting position on the traits measured. Similarly, full-season bolls that had opened naturally were chosen to help minimize any effects due to late or variable maturity. Bolls were picked with the carpel walls (burs) intact to ensure recovery of all motes (Rea, 1929a, 1929b). Within-boll seed yield and yield components were determined on a plot basis as following: (1) bolls per plant (B/P), (2) Boll weight (BW, g), (3) Lint percentage (LP, %), (4) Lint mass or boll size (LM, g boll^{-1}), (5) Seed mass or seed size (SM, mg seed^{-1}), (6) Seeds per boll (S/B): A seed was defined as a full-sized seed that resisted crushing, (7)Motes per boll (M/B): A mote was defined as all other reproductive structures in the locule, ranging from small unfertilized ovules (approximately 1-mm diameter) to nearly full-sized seed structures that could be crushed easily (pops), (8) Ovules per boll (O/B): determined by summing seeds and motes, and (9) Seed-setting efficiency (SSE, %): determined as percentage by dividing S/B by O/B.

Individual and combined data were analysis according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Developing crop cultivars with high seed cotton yield is considered to be a principal aim of Egyptian cotton breeding programs. Within the boll, yield can be dissected further. Seed cotton comprises two primary components, the number of seeds per boll and number of fibers borne on these seeds.

It is clear that significant genotypic variation for within-boll yield and yield components can be detected in the field. Thus, there is demonstrated sufficient genetic variation in these traits to facilitate trait improvement through selection, although the G×Y interaction suggests that multiyear screening may be needed. On a practical basis, determination of seeds per boll (S/B) requires more time and effort than other components. So it seems that direct selection for S/B would be more efficient in a breeding scheme to improve these within-boll yield components and possibly yield through the contribution of S/B as a primary yield component.

The four genotypes significantly differed for bolls per plant (B/P), lint percentage (LP), seeds per boll (S/B), motes per boll (M/B), ovules per boll (O/B) and seed-setting efficiency (SSE) but not for boll weight (BW), lint mass (LM) and seed mass (SM) (Table 1). Year effects were not significant for any trait except LP and SM, and genotypes responded differently to years only for O/B. These results agreed with those reported by Ragsdale and Smith (2007). Harrell and Culp (1976) suggested that breeders should select for increased bolls per unit land area with more seeds per boll. Bridge et. al. (1971) and Miller and Rawlings (1967) indicated that selection for increased lint yield resulted in cultivars with more seeds per boll and smaller boll and seed sizes. Results of this study, for seeds per boll (S/B) G.90 x Australian produced the highest value (20.94) followed by [(G.75 x 5844) x G.83] x G.80 (19.06) while G.80 cultivar produced the least (17.83) (Table 2.)

Table 1. Analysis of variance of within-boll seed yield components for parental genotypes of cotton (Gossypium barbadense L.) evaluated in 2010 and 2011.

		Mean Squares								
SV	df	B/P	BW	LP	LM	SM	S/B	M/B	O/B	SSE
Rep	6	1.134	0.108	1.62	0.021	0.003	0.77	0.28	0.24	8.18
Years (Y)	1	0.038	0.407	42.74**	0.003	0.065**	0.08	0.32	0.71	5.76
Genotypes (G)	3	24.34**	0.003	11.60**	0.012	0.010	14.24**	1.82**	6.93**	50.75**
G × Y	3	0.443	0.099	0.84	0.022	0.001	1.00	0.05	1.37*	0.69
Error	18	1.315	0.146	1.06	0.024	0.004	0.53	0.28	0.42	6.78

*, ** significant at P= 0.05 and P= 0.01 levels of probability, respectively.

In the current investigation, across genotypes and years, bolls per plant (B/P) from the old cultivars (G.80) to recent isolated hybrid (G.90 x Australian) increased from 11.25 to 15.41. Lint percentage ranged from 38.35 to 41.23%. Seeds per boll (S/B) increased from 17.83 to 20.94. While motes per boll decreased from 2.13 to 1.10 (Table 2). Thus, number of ovules per boll (O/B) increased from 19.96 to 22.05 and seed-setting efficiency (SSE) increased from 89.36 to 95.18. Thus, it appears that selection for increased yield during the last years has resulted in genotypes with increased lint percentage, more bolls per plant, and increased all within-boll yield components, bolls per plant (B/P), seeds per boll, ovules per boll (O/B), and seed-setting efficiency (SSE)., While boll size or lint mass (LM) and seed size or seed mass (SM) did not differ. Our results agree with those of Ragsdale and Smith (2007) who found that converted race stocks (CRS) accession M-9044-0162 had high seeds per boll (S/B), low motes per boll (M/B), increased ovules per boll (O/B), and increased seed setting efficiency (SSE).

In a study on within-Boll yield components of high yielding upland cotton cultivars, Bednarz et. al. (2007) which indicates the rational if the increased bolls per unit area was due to increased seeds per boll. As previously mentioned, G.90 x Australian produced more bolls per plant with more seeds per boll (Tables 2). This also resulted in greater ovules per boll (22.05) and lower motes per boll (1.10) with this isolated hybrid. The greater seeds per boll of G.90 x Australian was concomitant with greater seed-setting efficiency (SSI) comparative with other genotypes. The additional seed-setting efficiency produced with this isolated hybrid, however, resulted in a total seeds per boll that was greater than any of the other cultivars included in the study.

Concerning over genetic gain for yield, is an impetus for examining the components of yield, which include a number of plants per feddan, bolls per plant, seeds per boll, fibers per seed, and weight per fiber. Bowman et. al. (2001) in a study was to determine the genetic variation for initial ovule fiber cells in modern cotton cultivars, reported that there was a 20% variation in ovule fiber cell numbers among the parents under study.

While the four genotypes included in this investigation were not significantly different in lint mass per seed, lint mass produced per seed (1.27 mg boll^{-1}) was greater for G.90 x Australian (Table 2). Greater lint mass per seed occurred through production of more fibers per seed with this isolated hybrid relative to any of the other cultivars included in the study. Thus, while G.90 x Australian and [(G.75 x 5844) x G.83] x G.80 produced great lint mass per seed, high lint yield per unit land area (feddan) was maintained through greater lint percentage (41.23 and 40.33%, respectively) and bolls per plant (15.41and 12.55, respectively.)

Table 2. Mean within-boll seed yield components of four parental genotypes of cotton (Gossypium barbadense L.) when evaluated in 2010 and 2011.

Genotype	B/P no.	BW G	LP %	LM g boll^{-1}	SM mg seed^{-1}	S/B no.	M/B no.	O/B no.	SSE %
G.90 x Australian	15.41	3.07	41.23	1.27	0.99	20.94	1.10	22.05	95.05
[(G.75 x 5844) x G.83] x G.80	12.55	3.06	40.33	1.23	0.96	19.06	2.10	21.16	90.18
G.80	11.25	3.06	38.35	1.17	1.04	17.83	2.13	19.96	89.36
G.90	13.35	3.10	40.04	1.24	1.01	18.53	1.79	20.33	91.21
$LSD_{0.05}$	1.20	NS	1.08	NS	NS	0.76	0.55	0.68	2.73
CV%	9	12	3	12	6	4	29	3	3

Motes per boll (M/B is higher in some published reports (Davidonis et al., 2000; Saranga et al., 1998). This could be attributed to genotypic effects of the lines chosen for that population, but as environmental factors to have more substantial effects on motes number (Saranga et al., 1998), it appears that environmental effect due to season is a likely cause for this observation

While we did not test this hypothesis, it is possible that seed size (seed mass) is the primary force driving within boll yield components. All genotypes were not significantly different in seed mass or seed size which ranged between 0.96 to 1.04 g seed^{-1} (Table 2). It is interesting to note that yield components in this investigation did not differ between the two isolated hybrids and the two cultivars under study.

Throughout the last years of cultivar development it appears that lint percentage has increased by as much as 3%. The question arises, how much more can lint percentage increase? If fiber quality becomes less desirable with increased lint percentage and decreased seed mass then further increases in lint percentage are not advisable. Thus, selection for increased lint mass may be the next reasonable selection criterion.

Miller and Rawlings (1967) suggested that increased lint yield through selection for increased lint percentage has not only reduced boll mass and seed mass, but also fiber length and fiber strength. Stewart and Kerr (1974) also indicated that selecting a lint percentage alone to increase yield which could compromise seed mass and fiber length. It has been suggested that fiber length varies by fiber location on the seed, seed location within the boll, and boll location on the plant (Bradow and Davidonis, 2000). Bednarz et. al. (2007) suggested that cultivars with small seeds compensate for production of small bolls with less mass of fibers per seed through production of more bolls and seeds per unit land area. Thus, if a particular location on the seed or within the boll is a source of short fibers, the problem could become exacerbated when inadvertently selecting small seeds.

Previous research has identified multiple combinations of lint and fiber parameters that have served as selection criteria. High lint percentage combined with an increased number of medium to small seeds has been most frequently utilized (Miller and Rawlings 1967; Bridge et al., 1971; Gulp and Harrell 1975; Harrell and Gulp 1976). Small seed size has been associated with an increased number of seeds per boll and could influence harvested seed per area as well as seed surface area and fibers per seed.

Selection based upon lint percentage led to increased lint yield and ultimately, smaller seeded cultivars. Conversely, smaller seeds could improve lint percentage values. However, smaller seeds would contain smaller cotyledons and could result in a decreased stand. Thus, medium sized seed were optimal

The genotypes with the greatest potentiality to improve within-boll seed yield components in this study are the isolated hybrids G.90 x Australian and [(G.75 x 5844) x G.83] x G.80. Consistently across both years G.90 x Australian and [(G.75 x 5844) x G.83] x G.80 increased S/B, reduced M/B, increased O/B and increased SSE.

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المحصول و مكوناته داخل اللوزة لأصناف القطن المصرية عالية المحصول

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اجرى هذا البحث بهدف التعرف على سبب تفوق محصول الهجن المبشرة المعزولة بالوجه القبلى على الأصناف التجارية المنزرعة. اجرى البحث خلال موسمي (2010 –2011) بمحطة بحوث سدس. اشتملت الدراسة على اربعة تراكيب وراثية من القطن المصري وهى اثنين من الاصناف المنزرعة(جـ 80 و جـ90) بجانب هجينين مبشرين(الهجين جـ 90 × استرالى و الهجين [جـ83×(جـ75×5844)]× جـ80) باستخدام تصميم قطاعات كاملة العشوائية ذات 4 مكرارات . وتم تجميع البيانات عن الصفات المحصولية الداخلية للوزة ومكونات المحصول.ويمكن تلخيص اهم النتائج المتحصل عليها من هذه الدراسة كالاتى:

وجود اختلافات معنوية بين تلك التراكيب الوراثية تحت الدراسة فى صفات عدد اللوز للنبات و تصافى الحليج و عدد البذور فى اللوزة وعدد الموتس باللوزة وعدد البويضات باللوزة وكفاءة انتاج البذور. فى حين صفتى حجم اللوزة والبذرة لم تصل للمعنوية وان كان هناك تفوق للهجن المبشرة.

اظهرت الهجن المبشرة وخاصة الهجين (جـ 90 × استرالى) تفوق معنوى على الاصناف التجارية المنزرعة فى عدد اللوز بالنبات والتصافى وعدد البذور وعدد البويضات باللوزة مع قلة عدد الموتس وزيادة كفاءة انتاج البذور. مما يعطى دليلا على سبب التفوق المحصولى للهجن المبشرة على الاصناف التجارية المنزرعة.