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Backcross Techniques in Transferring Insect Resistance and Good Fiber Qualities to Naturally Colored Cotton

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ABSTRACT

The backcross method was used to transfer traits of resistance with regard to some cotton insects and the good fiber qualities of Salid 1 (SD1) and 413, the recurrent parents, respectively, to naturally colored cotton varieties, the non recurrent parents, (Green, Dark Green, Brown and Red Brick). The experiment was conducted at Suwan Farm, Nakhon Ratchasima from 2002 to 2006. Both the parent types and backcross progenies (SD1green, SD1dark green, SD1brown and SD1red brick) obtained were compared in terms of yield, fiber qualities and hopperburn rate during 2006 to 2008. The results indicated that in 2006, all backcrosses gave significantly lower seed cotton yields than those of their recurrent and non recurrent parents, except SD1green and SD1brown. In 2007, only SD1 red brick had a significantly higher yield than that of its non recurrent parent, Red Brick. There were no significant differences in terms of 2008 agronomic performance among all parents and the backcrosses. The high volume instrument (HVI) average results showed that all backcrosses, except SD1 413, had the fiber length determined as short. Fiber strength (g/tex) of each backcross also expressed better results than that of its recurrent parents. Only SD1 redbrick showed improved fiber elongation compared with its non recurrent parent, though it was only slight. The naturally colored cotton varieties, Brown and Dark Green, were significantly lower than their progenies, SD1brown and SD1 dark green, in terms of leafhopper numbers, during the years 2006 and 2007, respectively. In 2006, all backcrosses had a hopperburn rating slightly better than that of both their parents. The 2007 ratings of most backcross progenies were equal to the parents, except for SD1 green and SD1 brown, which were better.

Keywords: naturally colored cotton, backcross breeding, insect resistance, fiber qualities

INTRODUCTION

Some cotton is naturally colored - it grows that way and does not need to be dyed. “Color-grown” cotton has its roots in the ancient Americas. For thousands of years, weavers cultivated native, colored cottons that were white, tan, green, yellow, red and brown. During the 1990s, color-grown cotton was back in production, due to the efforts of Sally Fox, an inventor from California, who cultivated long-fibered, colored cotton, and created her own-patented cotton called “Fox Fibre”. Most Fox Fibre is grown organically, and requires minimal processing, because it does

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not need to be dyed. Today, it is used in a wide variety of products, including clothing, bedding and furniture (www.treehopper.com/files/2005/04/color_grown_cot.php)

Naturally colored cotton, as indicated by several sources, was produced for indigenous and commercial uses in many countries, including Peru, China, Egypt, the United States of America and Russia during the 1800s and 1900s (Dabney, 1896). However, the fiber qualities of the colored cotton were not suitable for modern textile machines; thus, today, most people only associate cotton with the color white. Hormchan *et al*. (2005) reported the key insect pests of naturally colored brown and green cotton to be similar to those of white cotton. The predominant insects found in cotton fields are jassid (*Amrasca biguttula*), bollworm (*Helicoverpa armigera*), whiteflies (*Bemesia tabaci*), cotton aphids (*Aphis gossyppi*) and pink bollworm (*Pectinophora gossypilla*). Among these, the most serious one is jassid, which causes a lot of damage in all stages of cotton growth.

The backcross method was first proposed as an appropriate breeding method for cereal crops in 1922 (Harlan and Pope, 1922). Since then, backcrossing has become a widely used plant breeding approach in diverse crop species. Backcrossing in cotton was apparently first used in the development of 'Griffin', over 50 years before geneticists showed the method was scientifically sound for plant improvement (Ware, 1936). At the time, 'Green Seed', an older upland, was crossed with 'Sea Island' (*Gossypium barbadense* L.) and then backcrossed to Green Seed several times to produce an essentially green-seeded upland cotton with the long, fine fiber of Sea Island. Jenkins and Harrell (1950) described several case histories where backcrossing was used successfully in cotton to improve targeted characteristics. Meredith (1977) used backcross breeding to derive improved combinations of lint yield and fiber strength in cotton. The backcross method was used to develop all of the initial, transgenic cotton cultivars with Bollgard (Monsanto Co., St. Louis, MO), Roundup Ready (Monsanto Co., St. Louis, MO), or both traits, and almost all others since that time (Verhalen *et al*., 2003). Since yield and quality are suboptimal, partly due to insect damage, the current study was aimed to improve leafhopper resistance, as well as the agronomic performance of naturally colored cotton, using backcross breeding.

MATERIALS AND METHODS

Backcross process

In 2002, SD1 was used as the recurrent parent in a backcross to transfer its insect- resistant attributes to naturally colored cotton of brown, green, dark green and red brick (the non recurrent parents). After F_1 was obtained, the resistant line (SD1) was backcrossed to the F_1, and plant selection for color fiber of desirable qualities and resistance to cotton insect pests was made for further backcrossing up to BC_5 seeds. These seeds were then planted for the next backcross using the selected line with high fiber quality from the breeding stock, 413. This line was then crossed with naturally colored SD1 (BC_5) progeny plants and used as the recurrent parent through BC_5 seeds. During each backcross, the plants with good fiber and slightly severe damage from cotton key pests were selected.

Field trial

From 2006 to 2007, preliminary yield tests were performed at Suwan Farm using three replicates in plots that were 10 m in length and 4 m wide. The spacing between plants and rows was 1 m. Ammonium sulfate was top-dressed at the rate of 25 kg/rai 20 days after planting. Cotton plants were thinned to one plant per hill. Plant height, days of flowering, yield, and fiber quality were recorded. Both neem extracts and Super Q were applied at a weekly interval to ensure crop growth, together with Unilate, as a foliar spray. Sprinkle and furrow irrigation were applied weekly to ensure normal growth.

The backcross progenies were evaluated for leafhopper resistance. The number of leafhoppers was recorded as the average found on five plants. Leafhopper damage was assessed using the following hopperburn scores (Renou *et al.*, 1998): 0 = no leaf injury, 1 = beginning of yellowish margins, 2 = yellowish margins, 2.5 = beginning of reddish margins, 3.0 = spread of yellowish to lamina, 3.5 spread of reddening to lamina, 4.0 = beginning of drying on margins, 5.0 = hopperburn symptom on all margins, 6.0 = spread of hopperburn to lamina, and 7 = all leaves dried or burned.

Data analysis

Lint samples were sent to the laboratory of Kongkiat, Inc., at Saraburi for determination of micronaire, elongation, fiber strength, 2.5% span length (2.5% SL), and maturity ratio by HVI analysis. Data for all traits and leafhopper numbers were subjected to analysis of variance testing. Means were separated according to Least significant difference (LSD) and Duncan's multiple range test (DMRT).

RESULTS

In 2006 (Table 1), there was no significant difference found in plant height between SD1 and 413, the recurrent parents, while only 413 was significantly different from the non recurrent parents and the backcross progenies. Dark Green, having 62 days in flowering, seemed to produce progeny, SD1 dark green, with significantly greater plant height than the others. The Brown and Red brick varieties gave their backcross progenies, SD1 brown and SD1 red brick, the same flowering period. The seed cotton yield in SD1 was not observed to be significantly different from that of SD1green and SD1brown progenies. All backcrosses gave significantly

Table 1 Yield performance of backcrossed materials in comparison with their parents at Suwan Farm in 2006.

Parents/backcross progenies	Plant height (cm)	Flowering period (d)	Seed cotton yield (kg/rai)
SD_1	104.8 ab	53 c	391.4 a
Green	102.0 bc	60 b	243.0 ef
Dark Green	103.3 bc	62 a	271.9 def
Brown	99.0 c	54 c	273.3 def
Red Brick	101.7 bc	54 c	232.3 f
413	110.0 a	54 c	318.0 bcd
SD_1 413	95.3 bc	57 bc	271.5 def
SD_1 green	99.7 bc	62 a	361.6 abc
SD_1 dark green	104.3 b	62 a	308.0 cde
SD_1 brown	104.3 b	54 c	387.5 ab
SD_1 red brick	102.0 bc	54 c	293.0 cef
Means	103.1	57	307.9
CV (%)	3.01	1.10	13.15
F-test	*	**	**
LSD 0.05	5.33	1.07	69.48

Note: Means followed by different letters in the same column indicate significant differences at the 5% level (LSD 0.05).

lower seed cotton yields than those of their recurrent and non recurrent parents, except SD1green and SD1brown, which had significantly higher yields than the green and brown varieties. No significant differences were observed among the backcross progenies.

Table 2 shows the plant height of SD1 and the Brown and Red Brick varieties not to be significantly higher than the backcross progenies, SD1 brown and SD1 red brick. Similar results with the flowering period were also observed between the Green and SD1 green backcrosses and between the Brown and SD1 brown progenies. The flowering period was significantly shorter in the Dark Green progeny than the other progenies of SD1 dark green. No significant differences among seed cotton yield were observed in SD1, Green and SD1 red brick, from those of SD1 413 and SD1 green progenies. Only SD1 red brick had significantly higher yield than that of its non recurrent parent, the red brick variety.

Table 3 shows that there were no significant differences among the agronomic performances of all categories of both recurrent and non recurrent parents and the backcross progenies.

HVI analysis by the Thailand Textile Institute of the fiber qualities of the parents and their progenies (Table 4) revealed that the Brown, Red brick, SD1 brown and SD1 redbrick samples had premium grade micronaire (fineness value), whereas the micronaire of the recurrent parents fell into the base range and those of all green shades of both non recurrent parents and their backcross progenies were classified as discount. The data showed the fiber length (inch) of SD1, 413 and SD1 413 to be medium, while the rest were classified as short length. Fiber maturity (%) and fiber strength (g/tex) also expressed better results in the recurrent parents and SD1 413 than in any naturally colored cotton. Only SD1 redbrick had improved fiber elongation compared to its non recurrent parent, though it was in the low range.

Table 2 Yield performance of backcrossed materials in comparison to their parents at Suwan Farm in 2007.

Parents/backcross progenies	Plant height (cm)	Flowering period (d)	Seed cotton yield (kg/rai)
SD_1	92.0 ab	58 b	196.7 a
Green	80.0 bc	67 a	171.0 abc
Dark Green	55.0 d	47 d	135.0 ef
Brown	100.3 a	58 b	125.0 f
Red Brick	90.0 ab	52 c	146.7 cdef
413	82.7 bc	57 b	155.3 bcde
SD_1 413	88.6 bc	68.4 a	210.56 a
SD_1 green	82.7 bc	67 a	171.3 abcd
SD_1 dark green	71.7 cd	53 c	160.7 bcde
SD_1 brown	101.7 a	58 b	142.7 def
SD_1 red brick	89.7 ab	57 b	176.3 ab
Means	84.6	58	158.07
CV (%)	11.66	3.74	10.48
F-test	**	**	**
LSD 0.05	16.91	3.69	28.42

Note: Means followed by different letters in the same column indicate significant differences at the 5% level (LSD 0.05).

Table 3 Yield performance of backcrossed materials in comparison to their parents at Suwan Farm in 2008.

Parents/backcross progenies	Plant height (cm)	Flowering period (d)	Seed cotton yield (kg/rai)
SD_1	91.7	55	277.3
Green	91.7	50	272.7
Dark Green	90.0	50	265.3
Brown	91.7	55	326.7
Red Brick	90.0	55	291.3
413	86.7	50	370.7
SD_1 413	89.0	52	301.0
SD_1 green	86.7	54	312.0
SD_1 dark green	85.0	49	250.0
SD_1 brown	93.3	51	326.7
SD_1 red brick	83.3	53	316.7
Means	89.0	52	300.9
CV (%)	8.30	5.84	24.96
F-test	ns	ns	ns
LSD 0.05	12.67	5.23	128.85

In 2006 and 2007, all backcross progenies were evaluated for the number of leafhoppers and the hopperburn rating for comparison with the recurrent parents and the non recurrent parents. The data from both years could not be compared due to different climatic conditions in each year. Table 5 reveals only that Brown and Dark green, the non recurrent parents, had significantly lower leafhopper numbers than their progenies, SD1 brown and SD1 dark green, during the years 2006 and 2007, respectively. Hopperburn ratings in 2006 indicated that all backcrosses were in a slightly better state than both their parents. The 2007 ratings of most backcross progenies were equal to their parents, except for SD1 green and SD1 brown, which were better.

DISCUSSION

The quality of cotton fiber comes from several traits, including length, fineness, and strength. Traditional plant breeding approaches that strive to improve yield and fiber quality in parallel have been hindered by complex antagonistic genetic relationships between important fiber and agronomic traits (Green and Culp, 1990). These data indicated that SD1 and 413 were generally good combiners for achieving finer fiber and improving yield. Ratanadilok and Hormchan (1985) revealed SD1 to have antibiotic resistance to *Helicoverpa armigera* in an experiment involving feeding insects with fresh parts of the cotton plant (young leaves and squares). In this backcross breeding, SD1 was used as a recurrent parent to give a resistant trait to leafhopper (unpublished data), while the selected line, 413, was used for high fiber quality. The progenies from backcrossing gradually showed some improvement at BC_5, though not much. Tests for high fiber quality, especially fineness value, for the naturally colored cotton have been conducted continuously until now, but still, they are not much improved, suggesting that fiber strength and fineness may be governed by a single major gene or a closely linked cluster of genes (Meredith, 2005). Fiber quality characteristics

Table 4 Average fiber qualities analyzed from different backcross breeding materials and their parents, grown at Suwan Farm in the period 2006-2008.

Parents/backcross Progenies	Fiber fineness (micronaire)	Fiber maturity (%)	Fiber length (inch)	Fiber strength (gm/tex)	Fiber elongation (%)
SD_1	4.7	0.9	0.99	27.8	7.0
Green	2.8	0.8	0.86	20.2	5.1
Dark Green	2.7	0.8	0.87	20.0	4.7
Brown	3.9	0.8	0.89	22.9	6.9
Red Brick	4.0	0.8	0.85	21.8	4.0
413	4.6	0.9	1.04	27.1	7.7
$SD_1$413	4.6	0.9	1.11	29.9	5.9
SD_1 green	2.8	0.8	0.85	20.9	6.2
SD_1 dark green	2.7	0.8	0.90	20.7	5.0
SD_1 brown	3.9	0.8	0.92	23.3	7.0
SD_1 red brick	4.2	0.8	0.87	22.0	5.1

Note : Fiber qualities determined in accordance with US Cotton Chart 2008.

Fiber fineness (micronaire)
3.7 – 4.2 = premium
3.5-3.6; 4.3 – 4.9 = base
below 3.4 and above5 = discount

Fiber strength (gm/tex)
below 23 = weak
24-25 = intermediate
26-29 = base
30-32 = strong
above 32 = very strong

Fiber length (inch)
below 0.99 = short
0.99 – 1.10 = medium
1.11 – 1.28 = long
above 1.26 = extra long

Fiber elongation (%)
below 5 = very low
5.0-5.8 = low
5.9-6.7 = average
6.8-7.6 = high above
above 7.6 = very high

Fiber maturity (%)
below 0.7 = uncommon
0.7-0.8 = immature
0.9-1.0 = mature
1.0 = very mature

Table 5 Average leafhopper numbers and hopperburn ratings in backcross material at Suwan Farm in 2006 and 2007.

Backcross families	Number of leafhoppers		Hopperburn rating	
	2006	2007	2006	2007
SD1	3.9 b	1.2 ab	5.0	1.0
Green	3.7 b	1.8 ab	4.0	2.0
Dark green	3.4 b	2.4 a	4.0	1.0
Brown	5.2 a	2.0 ab	4.0	3.5
Red brick	3.9 b	1.6 ab	3.5	1.0
413	5.7 a	1.2 ab	3.5	1.0
SD1 413	4.1 ab	1.4 ab	3.5	1.0
SD1 green	4.1 ab	0.8 ab	3.5	1.0
SD1 dark green	4.1 ab	0.2 b	2.0	1.0
SD1 brown	3.5 b	1.2 ab	4.0	1.0
SD1 red brick	4.5 ab	1.2 ab	3.5	1.0

Note: Means followed by the same letter in the same column are not significantly different as determined by DMRT at p=0.05.

possessed low heritability and using a backcross or recurrent selection process should be undertaken together with selection pressure in the F_3 generation (Meredith, 1990). Most of the backcrossed progenies expressed slightly higher fiber qualities than the originally colored parents, but not higher than those of the recurrent parents. However, these fibers could satisfy the requirements for middle- and low-grade spinning, especially for local weaving. Fox Fiber naturally colored cottons were reported to have fineness values of 2.5-3.0 for green and 3.0-4.0 for brown colors (http://www.spinnyspinny.comarticles/coloredcotton.html); hence, the green and brown colored backcrosses obtained had similar fineness values to those of Fox Fibre.

The numbers of leafhoppers on both parents and their progenies in 2007 seemed to be lower than in 2006, resulting in lower hopperburn grades as well. This could have been due to the different climatic conditions in each year, with less rain in 2006 than in 2007, according to the meteorological data from Suwan Farm. A dry climate was found to be more favorable to leafhopper development and reproduction. Similar results, which showed a greater abundance of leafhoppers in 2006 than in 2007 were reported by Hormchan and Wongpiyasatid (2008). Yet, it could not be claimed that the 2007 backcrosses were better than the 2006 ones, since, in both years, neither the numbers of leafhoppers nor the hopperburn rates were significantly different in their recurrent and non recurrent parents. The results from the 2007 hopperburn grades expressed resistance to leafhopper s in some backcross progenies, for example, in SD1green and SD1 brown, compared to their non recurrent parents.

CONCLUSION

The recurrent parents, SD1 and 413, including their progeny, SD1 413, had the best fiber qualities and yields, which were better than the backcrosses, SD1dark green, SD1green, SD1brown and SD1red brick, while those of the non recurrent parents, Green, Brown and Red brick, were equal to or less than their backcross progenies. The hopperburn grades of the backcrosses indicated slightly better resistance to leafhoppers than the recurrent and non recurrent parents. Among the backcross progenies, SD1green and SD1 brown had leafhopper numbers less than their non recurrent parents. SD1brown was more improved compared to its parents.

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