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1 ***Research paper***

2 **Effect of Skip-Row Cotton Planting Pattern and Plant Density**

3 **on Cotton Growth, Yield, Fiber Quality, and Net Returns**

4

13 EFFECTS OF TWO PLANTING PATTERNS AND PLANT DENSITIES ON COTTON GROWTH, YIELD,
FIBER QUALITY AND NET RETURNS

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2 ABSTRACT

3 **Aims:** To evaluate the effect of two cotton planting patterns across two plant densities to
4 determine the effect on cotton growth, yield, fiber quality, and net returns.

5 **Study Design:** Randomized complete block design with a 2 x 2 factorial treatment
arrangement

6 with 3 replicates was used.

7 **Place and Duration of Study:** Studies were conducted during the 2003 and 2004 growing
8 season on a producers farm located south of Eagle Lake, Texas in Colorado County
(29.49360 N,
9 96.34060 W).

10 **Methodology:** Rows were spaced 91.4-cm apart on slightly raised beds. Plot size was eight
11 rows by 972 m long. The two different factors included two row planting patterns, the solid
12 pattern with every single row planted and the skip-row pattern with a 2x1 planting pattern
where

13 2 rows are planted and 1 row is left fallow. For the skip-row pattern, rows three and six
were not

14 planted in the 8 row plot. The second factor was seeding rate with two plant populations
(84000

15 and 126000 plants/ha).

16 **Results:** In neither year were any differences seen with seeding rate. In 2003, days to cut-
out

17 with the skip-row pattern were ~~92.3~~ 92.4 while with the solid pattern days to cut-out were
~~87.8~~ 87.9 and

18 plant height with the skip-row pattern was 100 cm while with the solid pattern, plant height
was

19 87 cm. Lint yield was 1504 kg/ha for the solid pattern while with the skip-row pattern lint
yield

20 was ~~1247~~ 1347 kg/ha. In 2004, lint yield with the solid pattern was ~~26%~~ 27% greater than
the skip-row

21 pattern. ~~Slight differences~~ No differences between the two planting patterns were observed
during 2004 in days to

22 cut-out or plant height. In both years, the solid planting pattern produced a net dollar
value/ha

23 increase over the skip-row pattern.

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Keywords: cotton, skip-row, solid pl 1 anting, plant growth, net returns.

2 1. INTRODUCTION

3 The practice of alternating two planted rows of cotton with two blank rows has been used
4 for
5 over 50 years in many areas of the U. S. where cotton is grown under low annual rainfall
6 conditions, to decrease production costs, or when low prices favor skip-row planting
7 patterns
8 [1,2,3,4]. The use of skip-row planting increased in earlier years because allotment acreages
9 could be calculated on planted rows only rather than total land area and because skip-row
10 plantings result in higher lint yields with this system of computation [5]. Dick and Owings
11 [2]
12 reported results of a 3-yr study of skip-row cotton which showed increases in yield ranging
13 from
14 24 to 127%. They compared skip-row patterns, 4x4 and 2x2 with solid planting and the
15 greatest
16 yield increase (127%) came in 1956 from the 2x2 pattern. Research from the Mississippi
17 Delta
18 region of the U. S. indicated that yield response from the 4x4 design would be expected to
19 vary
20 according to seasonal conditions, and that the greatest advantage from this pattern resulted
21 from
22 the more favorable growing seasons [3]. Yield increases in the 4 year study from this
23 design
24 ranged from 25 to 73% [3]. Grissom and Spurgeon [6] reported that cotton planted on
25 Dubbs
26 and Bosket soils in a 4x4 pattern produced 45% more yield and the 2x2 pattern produced
27 67%
28 more than solid plantings. However, they reported no yield increase from skip-row planting
29 on
30 Sharkey clay where plants were approximately 61 cm tall.
31
32 Sturkie and Boseck [7] found that 3 year average yield increases for the 2x2 and 4x4
33 patterns
34 over solid plantings were 57 and 31%, respectively where 272 kg/ha fertilizer was used and
35 46
36 and 28%, respectively where 408 kg/ha fertilizer was used. Langsford [8] tested 11
37 different
38 systems of skip-row plantings, six of which involved interplanting with other crops [8]. He

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showed that all skip-row systems increased cotton yield from 10 to 60%, indicating that
cotton
benefitted from the skip-row design, whether those rows were planted to other crops or left
fallow. Other studies, depending on location, have shown skip-row lint yields for row
spacings
> 76-cm to be 54 to 100% of solid-planted yields on a land area basis [4,9,10,11,12].

5
6 With skip-row cotton, plants adjacent to the skipped rows partially compensate for lost yield
by
7 growing into the unplanted areas, such that the reduction in yield is less than proportional to
the
8 reduction in planted area [13]. This yield compensation may be due to less competition for
9 nutrients and soil moisture, greater light penetration to lower leaves, or some combination of
10 these factors [11].
11
12 Another strategy producers have utilized to decrease production costs is reducing the
cotton
13 seeding rate or plant densities [14]. Establishing an acceptable stand of cotton is paramount
to
14 obtaining high yields [14,15]. However, recent studies have shown no differences in cotton
yield
15 due to plant density [16,17,18,19,20]. The lack of yield differences can be explained by an
16 increased number of main stem nodes, and location of sympodial and monopodial bolls on
plants
17 grown at lower densities [14,15,16].
18
19 Current technology allows cotton to be effectively seeded and harvested in alternative
planting
20 patterns. Also, reducing cotton plant densities can be a practical option for producers to
decrease
21 production costs. However, little information is available concerning the effect of
alternative
22 planting patterns utilizing different plant populations along the upper Texas Gulf Coast
where
23 moisture is usually not a limiting factor. Therefore, the purpose of this study was to
compare

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cotton response to conventionally planted pattern versus the 1 skip-row 2x1 pattern along the
2 upper Texas Gulf Coast. Partial budget analysis was used in this study to evaluate returns
for the
3 conventional and skip-row patterns.

4

5 2. MATERIALS AND METHODS

6

7 2.1 Field studies

8 Studies were conducted during the 2003 and 2004 growing season on a producers farm
located
9 south of Eagle Lake, Texas in Colorado County (29.49360 N, 96.34060 W) to compare
cotton

10 response of skip-row pattern (2x1) with solid plantings at two different plant populations.
 Soil
 11 type at this site near Eagle Lake was a Weswood silt loam (fine-silty, mixed, superactive,
 12 thermic Udifluventic Haplustepts) with 1.0 % organic matter and pH 7.2. These studies
 were in
 13 different fields each year but in the same general area. Fertilizer was applied by the grower
 as
 14 needed according to Texas A&M AgriLife Extension Service recommendations for cotton.
 Plots
 15 were maintained weed-free throughout the growing season using a preemergence
 application of
 16 flumeturon (Cotoran ®, Griffin, LLC, Valdosta, GA 31603) at 0.42 kg/ha plus S-
 metolachlor
 17 (Dual II Magnum®, Syngenta Crop Protection, Greensboro, NC 27419-0135) at the 0.43
 kg/ha
 18 applied in a 30-cm band over the top after cotton was planted. In 2003, the plot area was
 19 cultivated three times while in 2004, glyphosate at 0.6 L/ha was applied once and plots
 were
 20 cultivated three times.
 21
 22 FiberMax 832B was planted on April 1, 2003 while DPL 444 BG/RR was planted on
 March 30,
 23 2004 with an 8-row John Deere MaxEmerge II vacuum planter. FiberMax 832B was not

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available the second year of the study; therefore, DPL 444 BG/1 RR was used since it is also
 2 medium-early and both have the same maturity. Beginning at first bloom, weekly counts of
 3 nodes above white flower values were obtained by sampling ten plants from each plot.
 Twenty
 4 plants per plot were measured at the end of the season to determine final plant height.
 Number
 5 of bolls to produce a kilogram of lint was obtained by hand-harvesting 0.002 of a hectare at
 three
 6 different places in each plot.
 7
 8 Both sites were maintained under rain-fed conditions. Rainfall during the 2003 growing
 season
 9 was below normal for most of the growing season with July being the only month that had
 above
 10 average rainfall. Rainfall during the 2003 growing season was 41% below normal (Table
 1).

11 For the 2004 growing season, above normal rainfall was received for April, May, and June
with
12 below average rainfall for March and July. Overall, rainfall during the 2004 growing
season was
13 40% above normal (Table 1) [21].

14

15 **2.2 Plot harvest, partial budget, and statistical analysis**

16

17 Seed cotton yields were obtained by machine harvesting the middle two rows of each plot
and

18 weight was determined with a portable cotton weigh wagon. In both years, a grab sample
of

19 approximately 600 grams of seed cotton from each of the plots was ginned on a 10-saw
Eagle

20 Laboratory Gin to determine lint yield and turnout. A 30 gram lint sample from each of the
plots

21 was then sent to the International Textile Center (Lubbock, TX) for fiber quality analysis.

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The economic analysis included in this study is based on partial 1 budgeting of net returns
above

2 seed and seed technology costs, in-furrow insecticide costs, banded herbicide costs, picking
costs

3 and ginning costs. This partial budgeting technique is appropriate since all other factors of
4 production were the same for both systems. 2012 prices were used in the partial budgets
with the

5 following assumptions for each year [22]. In 2003, FiberMax 832B had only Bollgard®
6 technology [23,24] but no glyphosate tolerance and the technology fee was \$92.50/bag. In
2004,

7 DPL 444 BG/RR had Bollgard® and Roundup-Ready® [25,26,27,28] technology with a
8 technology fee of \$262.70/bag. In both years all other assumptions were the same. As

shown in Tables 5 and 6, the ~~The~~ loan

9 value for solid and skip-row planting was \$1.194 kg/lint while seed cotton was \$292.11/
metric

10 ton. Seed cost was \$150/bag based on 250,000 seed/bag while the cost of thiamethoxam
seed

11 treatment was \$41.90/bag. S-metolachlor costs were \$2.56/ha while flumeturon costs were
12 \$1.61/ha. Picking charges was \$0.267/ kg of lint and ginning charge was calculated at
\$0.0606 /

13 kg of seed cotton.

14

15 Data were analyzed using PROC GLM with SAS (SAS Institute, Inc., Cary, NC) and a model

16 statement appropriate for a factorial design. Treatments means were separated by Fisher's
17 protected least significant difference test at $P=0.05$. Data for the two years were analyzed
18 separately due to slight differences in plant populations in each year of the study and also
due to

19 different rainfall patterns in each year.

20

21 **3. RESULTS AND DISCUSSION**

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Since environmental conditions were different in each year 1 of the study, it was thought to
2 analyze each year separately to determine if environmental conditions were a factor in the
3 results.

4

5 **3.1 Rainfall**

6

7 Rainfall amounts along the upper Texas Gulf Coast were variable for the two years (Table
1).

8 Rainfall in 2003 can be characterized as below average for all months of the growing season
with

9 the exception

10 of July which

11 had

12 approximately 2X of the normal monthly rainfall. In 2004, below average rainfall was
received

13 for March and July; however, rainfall amounts for April, May, and June were 1.4X, 1.7X
and 2.5X ~~1.96X~~ the total average

14 rainfall for those three months respectively (Table 1).

Table 1. Monthly rainfall during the growing season at the study locations
during 2003 and 2004.

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13 3.2 Seeding rate

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15 Seeding rate had no effect on any variable evaluated. Therefore, only differences in
16 planting
17 pattern are discussed. Other researchers have also noted the lack of plant density effect on
18 several variables. Seibert and Stewart [20] observed that plant density did not influence
19 plant
20 height; however, Seibert et al. [19] found a positive relationship between plant height and
21 plant
22 density. Pettigrew and Johnson [29] reported no differences between cotton plant densities
23 of 7,
24 9, 11, or 13 plants m² for plant height and total nodes/plant. Stephenson et al. [14] found
25 that the
26 percentage of total bolls associated with the first position??? (please specify) increased
27 with increasing plant
28 densities. In other research, O’Berry et al. [30] found no differences in the number of first
29 and
30 second position ??? (please specify) bolls per plant as plant densities increased. The effect
31 of plant densities on seed

Month 2003 2004 20-yr average

Monthly rainfall (mm)
March 33.3 65.0 80.8
April 8.6 117.4 83.8
May 4.1 205.7 119.4
June 96.5 321.6 126.5
July 175.3 7.9 83.1
August 23.9 98.8 88.9
Total 341.7 816.4 582.5

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cotton yield has also been variable. Stephenson and Brecke 1 [31] found that cotton seeded at
7

2 plants m² yielded 370 and 120 kg/ha less seed cotton and lint, respectively than the 7 plants
m² ?????

3 but that no other differences between plant densities were observed. Others have found that
lint

4 yield was not influenced by plant density when cotton was seeded in 90 or 97 cm rows

5 [16,17,19,20]. Plant density also had no effect on fiber quality [14,29,30]. Stephenson et al.

6 [14] reported that plant density had no effect on fiber length, micronaire, strength, or
uniformity

7 while O'Berry et al. [30] observed no effect of plant density on lint percentage. Other work

8 indicated that plant density did not influence fiber strength or uniformity, but micronaire
was

9 slightly affected [29]. In contrast, Darawsheh et al. [32] observed decreased fiber micronaire
and

10 length when plant densities were increased, but fiber strength and uniformity were not
affected.

11

12 3.3 Agronomic response to planting pattern

13

14 **A. Days to cut-out.** In 2003, the conventional pattern resulted in a 5% reduction in the
number

15 of days to cut-out over the skip-row pattern (Table 2) while in 2004 no differences were
noted

16 between the two planting patterns (Table 3). Since early crop maturation and harvest of
cotton

17 can enhance production efficiency by alleviating late-season risks associated with adverse
18 weather and insect problems [33], the reduction seen in 2003 is important in getting the
crop out

19 of the field.

20

21 **B. Plant height.** In 2003, the skip-row pattern produced a taller plant than the solid pattern
22 (Table 2) while in 2004 not much ~~no~~ differences in plant height were noted (Table 3).

Buehring et al. [9]

23 reported that row pattern did not have any effect on plant height. Seibert and Stewart [20]

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observed that plant density did not influence plant height; 1 however, Seibert et al. [19] found a

2 positive relationship between plant height and plant density. Pettigrew and Johnson [29]

3 reported no differences between cotton plant densities of 7, 9, 11 or 13 plants m² for plant height

4 and total nodes per plant.

5

6 **C. Open bolls and bolls/kg lint.** In 2003, solid planting produced more open bolls but no differences were seen with respect to ~~open bolls or~~

7 bolls/kg lint with either planting pattern (Table 2). Hawkins and Peacock [1] reported that the

8 solid planting produced smaller bolls than the skip row planting and they concluded that an 9 increase in boll size, along with more bolls per lateral branch and more lateral branches per plant

10 [34], contributed to increased yields from skip-row planting.

11

12 **D. Lint yield.** In 2003, the solid planting outyielded the skip-row planting by 157kg ~~257 kg~~ (Table 2)

13 while in 2004 the solid planting yielded 267 kg more cotton than the skip-row planting (Table 3).

14 Mixed results have been seen with skip-row vs solid plantings [1,2,4,5,10,11,12,14,34].

15 Hawkins and Peacock [1] reported that skip-row plantings increased cotton yield over solid 16 plantings by 20 to 75%. Kittock [5] reported that the skip-row plantings (1x1, 2x1, 2x2, 4x2, and

17 6x2) gave significant increases in lint yield of Pima cotton when computed on a planted area

18 basis ~~with. Kittock reported that~~ the most benefit from skip-row ~~was~~ obtained in the outside rows.

19 He also stated when computed on the total land area basis, all skip-row patterns gave reduced

20 yields. Bruce [35] found 27 and 34% yield increases from 2x1 planting, compared with solid

21 planting, and attributed some of the differences to more available soil water for plants in skip

22 row. Parvin et al. [4] stated that a hectare of solid cotton exhibited higher yields than a ~~an~~ hectare

of skip-row cotton. They also reported the narrower the skip, the closer the yield of the skip-row

2 cotton approached the yield of solid planted cotton.

3

4 3.4 Fiber quality

5

6 **A. Micronaire.** No **significant** difference in micronaire values **was were** seen in either year (Table 4). This is in

7 contrast to Larson et al. [13] who reported under nonirrigated conditions that micronaire values

8 were lower for skip-rows than for solid plantings. McAlister [30] and Vories et al. [37] reported

9 lower micronaire in narrow-row spacings than in wide-row spacings. However, Doederlein et al.

10 [38] found no differences in micronaire between solid and skip-row for 102-cm row spacings in

11 Texas while Hons and McMichael [11] reported higher micronaire for solid rows than skip-row

12 at 100-cm row spacing.

13

14 **B. Staple length.** In 2003, the skip-row pattern had **a slightly** longer staple length than the solid planting

15 while in 2004 no differences were noted (Table 4). Larson et al. [13] reported under irrigation

16 that the skip-row pattern had longer staple length than did solid rows. They speculated that 17 decreased staple length may be due to differences in harvest method. **What about your**

result interpretations ??? Bange et al. [39] in

18 Australia, reported increased staple length for skip-rows relative to solid rows at 100-cm 19 spacings.

20

21 **C. Uniformity and fiber strength.** No differences in uniformity or fiber strength with any 22 planting pattern were observed in either year (Table 4). Larson et al. [13] and Stephenson et al.

23 [14] also reported no differences in these lint quality factors with any planting pattern.

D. Elongation. In 2003, no differences in fiber elongation were noted with any planting pattern while in 2004 the solid planting pattern had a **slightly** greater elongation than the skip-row pattern (Table 4). No previous research could be found that reported on fiber elongation as affected by planting pattern.

3.5 Net returns when comparing planting patterns

In 2003, the advantage in net returns for solid planting over skip-row planting was **\$144.96/ha almost** ~~10 \$144/ha~~ (Table 5). While values for lint cotton and cotton seed were greater for solid planting, production costs were also always greater. Similar trends were seen in 2004 with net returns \$245.65/ha greater for the solid planting (Table 6). In contrast, Larson et al. [13] reported that net returns for 102-cm skip-row plantings were equivalent to 102-cm solid planting for low or high cotton lint prices in nonirrigated and irrigated studies. They stated that for base lint prices ranging from \$0.85 to \$1.38/kg, the savings in seed costs, technology fees, and harvest costs from skip rows were not enough to offset the yield reductions seen in skip-row with 102-cm row spacing. However, in the same study, Larson et al. [13] reported that skip-row plantings produced larger net returns than solid row plantings at 25- and 76-cm row spacing under low-lint price scenario (\$0.85/kg) in nonirrigated and irrigated studies. Thus, at low lint prices, savings in seed cost, technology fees, and harvest labor and machinery cost associated with skip-row plantings led to greater net returns than the solid plantings. These results support the theory of Parvin et al. [4]

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who stated that low prices favor skip-row plantings. To make 1 skip-rows more profitable than

2 solid plantings at high lint prices, a combination of increased yields from skip rows and
3 additional cost savings (e.g., in-row chemical costs) would be needed [13].

4

5 In our studies, no advantage was seen with the skip-row cotton planting with plant
6 populations

7 from 84000 to 126000 plant/ha as higher yields and greater net returns were seen with solid
8 plantings. Differences in fiber quality between the solid and skip-row plantings were not
9 consistently significant and therefore, along the upper Texas Gulf Coast, there seems to be
10 no

11 advantage to skip-row cotton plantings.

12

13 **CONFLICT OF INTEREST**

14

15 The authors have no conflict of interest with any of the entities mentioned in this
16 manuscript.

17

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Table 2. Cotton response to skip-row versus solid plantings in 2003.

Planting pattern	Plant population	Days to cutout	Plant ht	Number open bolls	Bolls/kg lint	Lint yield
	Number/ha	Number	cm	1000's/ha	Number	Kg/ha
Skip-row	84000	92.7	100.3	620.4	493.4	1357
	126000	92.0	99.3	627.0	481.8	1336
		~~-92.3~~ a 92.4	99.8a	623.7a	~~-487.7~~ a 487.6	1347b
Solid	84000	88.7	87.1	699.6	472.3	1476
	126000	87.0	87.1	741.4	505.3	1531
		~~-87.8~~ b 87.9	87.1b	720.5a	488.8a	1504a

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Table 3. Cotton response to skip-row versus solid plantings in 2004.

Planting pattern	Plant population	Days to cutout	Plant ht	Lint yield
	Number/ha	Number	cm	Kg/ha
Skip-row	84000	107.3	100.8	1057
	126000	105.3	99.1	1036
		106.3 a	~~-99.9~~ a 100.0	1047b
Solid	84000	104.0	94.7	1299
	126000	105.7	96.5	1328
		~~-104.8~~ b 104.9	95.6a	1314a

Table 4. Cotton fiber characteristics from skip-row versus solid plantings.

Planting pattern	Plant population	Micronaire		Staple length		Uniformity		Strength		Elongation	
		Units		Mm		%		Gr/tex		Units	
		2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Skip-row	84000	3.77	4.17	31.50	29.21	85.10	84.30	32.17	31.40	3.83	6.40
	126000	3.80	4.17	31.24	29.72	84.00	84.40	34.13	32.70	3.47	6.30
		~~3.78~~ a 3.79	4.17a	31.37a	~~29.46~~ a 29.47	84.6a	84.35a	33.15a	32.05a	3.65a	6.35b
Solid	84000	3.63	4.23	30.99	29.21	84.4	84.70	31.90	31.60	3.77	6.60
	126000	3.87	4.13	30.48	29.46	83.8	84.60	31.60	31.80	3.60	6.50
		3.75a	4.18a	~~30.73~~ b 30.74	29.34a	84.1a	84.65a	31.75a	31.70a	~~3.68~~ a 3.69	6.55a

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Table 5. Partial budget production costs for solid versus skip-row plantings in 2003 using 2012 budget values.^a

Variables Solid Skip-row

Difference

(Solid-skip row)

Yield (Lint kg/ha) 1504 1346 158

Turnout (%) 36.99 35.89 1.10

Seed cotton yield (Kg/ha) 4066 3750 316

Cotton seed yield (Kg/ha) 2406 2154 252

Lint value per ha at loan 1795.78 1607.12 188.66

Cotton seed value (\$/ha) 702.82 629.20 73.62

Seed costs (\$/ha) 75.34 50.11 (25.23)

Technology fee (\$/ha) 46.45 30.91 (15.54)

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In-furrow insecticide costs (\$/ha) 21.05 13.99 (7.06)

Banded herbicide costs (\$/ha) 25.45 16.98 (8.47)

Picking Costs (\$/ha) 398.56 356.69 (41.87)

Ginning costs (\$/ha) 246.40 227.25 (19.15)

Advantage for solid planting (\$/ha) 144.96

^a FiberMax 832B had only Bollgard® technology but no glyphosate tolerance and the technology fee was \$92.50/bag. The loan value for solid and skip-row planting was \$1.194 kg/lint while seed cotton was \$292.11/ metric ton. Seed cost was \$150/bag based on 250,000 seed/bag while the cost of thiamethoxam seed treatment was \$41.90/bag. S-metolachlor cost was \$2.56/ha while flumeturon cost was \$1.61/ha. Picking charge was \$0.265/ kg lint and ginning charge was calculated at \$0.0606/ kg seed cotton.

Table 6. Partial budget production costs for solid versus skip-row plantings in 2004 using 2012 budget values.^a

Variables Solid Skip-row

Difference

(Solid-skip row)

Yield (Lint kg/ha) 1328 1057 271

Turnout (%) 36.00 36.00 -

Seed cotton yield (Kg/ha) 3690 2935 755

Cotton seed yield (Kg/ha) 2125 1691 434

Lint value per ha at loan 1585.63 1262.06 323.57

Cotton seed value (\$/ha) 620.73 493.96 126.77

Seed costs (\$/ha) 77.54 51.59 (25.95)

Technology fee (\$/ha) 135.81 90.36 (45.45)

In-furrow insecticide costs (\$/ha) 21.67 14.41 (7.26)

Banded herbicide costs (\$/ha) 25.45 16.98 (8.47)

Picking Costs (\$/ha) 351.92 280.11 (71.81)

Ginning costs (\$/ha) 223.61 177.86 (45.75)

Advantage for solid plantings (\$/ha) 245.65

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^a DPL 444 BG/RR had Bollgard® and Roundup-Ready® technology with a technology fee of \$262.70/bag. The loan value for solid and skip-row planting was \$1.194 kg/lint while seed cotton was \$292.11/ metric ton. Seed costs were \$150/bag based on 250,000 seed/bag while the cost of thiamethoxam seed treatment was \$41.90/bag. *S*-metolachlor cost was \$2.56/ha while flumeturon cost was \$1.61/ha. Picking charge was \$0.265/kg lint and ginning charge was calculated at \$0.0606/kg seed cotton.