DISEASE RESISTANCE OF COTTON HYBRIDS WITH DIFFERENT LEVEL OF TOTAL AND (+) GOSSYPOL LEVEL IN SEEDS

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Abstract

The presence of gossypol in glands of cotton protects the plant from pests. However, there is limited information on how the level of (+)- and (-)-gossypol enantiomers affect resistance to insect and pathogens. We have evaluated the resistance of plants that exhibit the high (+)-gossypol seed trait to insects (i.e., *Helicoverpa armigera*) and diseases (i.e., *Thielaviopsis basicola, Rizactonia solani,* and *Xanthomonas malvacearum D*); effects of total seed gossypol on resistance to this insect and these pathogens was also evaluated. Field and greenhouse tests indicate that it should be possible to breed lines that exhibit the high (+)-gossypol seed trait and retain acceptable levels of insect and disease resistance together with acceptable levels of agronomic properties. The best lines in this study were crosses between the U.S. line BC_3S_1-47-8-1-17 and the Uzbek line S-6530; this cross gave good/acceptable resistance to all pathogens in both spring and autumn.

Introduction

Cottonseed protein currently is underutilized because of the presence of a toxic compound called gossypol which is contained in glands in different parts of the plant and protects the plant from pests (Bottger and Patana, 1966). When glandless cotton plants with edible cottonseed were field tested, the results were discouraging. Glandless plants in the field were completely defoliated by insects whereas adjacent glanded plants showed little or no damage (Bottger et al., 1964).

Gossypol is biosynthesized by the free radical coupling of two molecules of hemigossypol (Jaroszewski et al., 1992; Liu et al., 2008). During this coupling reaction, two optically active enantiomers are formed. One of these is referred to as (+)-gossypol and the other as (-)-gossypol. Most of the toxicity of gossypol resides in the (-)-enantiomer (Wu et al., 1986). The ratio of (+)- to (-)-gossypol in seed has been reported to vary between a high of 98:2 and a low of 31:69 (Cass et al., 1991; Stipanovic et al., 2005).

The influence of gossypol enantiomers on resistance to different insects and diseases have been reported (Yang et al., 1999; Stipanovic et al., 2006; Puckhaber et al., 2002; Yildirim-Aksoy et al., 2004; Namazov et al., 2008). However, extensive tests under field conditions have not been conducted. To fill this knowledge gap, we initiated a study to determine how the ratio of (+)- to (-)-gossypol in the seed might affect resistance to the pathogens *Thielaviopsis basicola, Rizactonia solani,* and *Xanthomonas malvacearum D*, and to the insect *Helicoverpa armigera*; total gossypol as also evaluated in this study.

Materials and Methods

Cotton Varieties, Lines and Progenies

The American cotton lines used in this study were BC_3S_1-47-8-1-17 and BC_3S_1-1-6-3-15 provided by A. A. Bell. The lines exhibit a high percent (>93.0%) of (+)-gossypol in seeds. The hybrid progenies were developed by crossing the U.S. lines with Uzbek varieties S-6524, S-6530, and S-6532. In all crosses the Uzbek line was used as the male parent. Cotton breeding materials were tested according to the methodology accepted in the Uzbek Scientific Research Institute of Cotton Breeding and Seed Production (Belousov et al., 1973). Statistical analyzes were conducted according to Dospekhov (1985).

Experiments were conducted in the greenhouse and under field conditions in the spring and autumn of 2011. The experimental field plots have typical serozem soils with small residual humus (up to 1%) and deep ground water level (7-8 m). The long-term precipitation per year averages 360 mm^3, which occurs mainly during the autumn-winter-spring period. Field plots were laid out in a completely randomized block design. Plots were single rows spaced 60 cm with single plants spaced 25 cm within rows. Plants were irrigated 4 times during of vegetation period. Plots received 240 kg/ha N_2O, 160 kg/ha P_2O_5, and 120 kg/ha K_2O.

Measurement of Pathogen Damage

We investigated resistance of F_5 progenies with different percentages of (+)-gossypol in seed to *Thielaviopsis basicola, Rizactonia solani,* and *Xanthomonas malvacearum D*. In the field study, the soil was infected by adding of 2.5-3.0 mg mycelia of *Rizactonia solani*, or 3.0-4.0 mg mycelia of *Thielaviopsis basicola* to a hole in which the seed was planted. To test for resistance to *Xanthomonas malvacearum D*, seeds were first treated with a water suspension of *Xanthomonas malvacearum D* (4 g mycelia/liter of water) for 24 hr before planting. Susceptible plants were evaluated at the 4-5 leaf stage in the spring and before harvesting in September (According to Naumov, 1937; Khitrov, 1968; Khasanov and Babanazarov, 1976).

Measurement of Insect Damage

Screening for resistance to *Heliothis armigera Hb* was conducted by artificially introducing a moth to the plant during flowering and again at maturity and counting the number of damaged bolls (Shvetsova and Em, 1991).

Results and Discussion

Disease Resistance

All field tests were conducted in the spring and fall of 2011. In the spring, we found all of the local varieties were more resistant than the U.S. accessions to *R. solani*; S-6532 was the most resistant (Table 1). Between the U.S. accessions, BC_3S_1-47-8-1-15 was more resistant (9.02% susceptibility). Most of the crosses were more susceptible than the Uzbek parent with the exception of the progenies $F_5BC_3S_1$-47-8-1-17 x S-6532 and BC_3S_1-47-8-1-15 x S-6524 that exhibited the 70-80% (+)-gossypol seed trait and they were essentially identical. Susceptibility of these crosses was 5.4% and 6.0%, respectively. The susceptibility between the progenies of $F_5BC_3S_1$-47-8-1-17 x S-6524 and $F_5BC_3S_1$-1-6-3-15 x S-6532 with the 70-80% (+)-gossypol and the >90% (+)-gossypol were similar. Most crosses with the >90% (+)-gossypol seed trait showed a susceptibility similar to progenies with the 70-80% (+)-gossypol seed trait in the spring. The exception were the >90% (+)-gossypol progenies $F_5BC_3S_1$-47-8-1-17 x S-6530 and $F_5BC_3S_1$-1-6-3-15 x S-6530 which were more resistant than the corresponding 70-80% (+)-gossypol progenies. In the autumn, all crosses with accession BC_3S_1-47-8-1-17 whose progeny exhibited the 70-80% (+)-gossypol seed trait were less susceptible than their Uzbek parent, while those exhibiting the >90% (+)-gossypol seed trait were more susceptible than their Uzbek parent (Table 2). Almost all crosses with the >90% (+)-gossypol (with exception of the >90% (+)-gossypol progeny $F_5BC_3S_1$-1-6-3-15 x S-6530) were more susceptible than their corresponding 70-80% (+)-gossypol progenies to *R. solani*.

We observed differences in susceptibility of the parents in the spring with regard to total seed gossypol; the comparatively low total gossypol U.S. accessions showed higher damage. However, no correlation between total seed gossypol and resistance to *R. solani* was observed in either the spring or autumn in the F_5 progenies.

The results from the spring study with *T. basicola* indicates that most of the crosses that exhibited >90% (+)-gossypol seed trait were more resistant (Table 3) than the Uzbek parents S-6524 and S-6530 (except the S-6532, which was the most resistant). However, >90% (+)-gossypol crosses $F_5BC_3S_1$-47-8-1-17 x S-6524 and $F_5BC_3S_1$-1-6-3-15 x S-6532 were less resistant (score 10.2 and 10.1, respectively). In the autumn, the most resistant progeny that exhibited >90% (+)-gossypol in seed compared to their parent were progeny from S-6530 (Table 4). Notable were the >90% (+)-gossypol progenies $F_5BC_3S_1$-47-8-1-17 x S-6524 and $F_5BC_3S_1$-47-8-1-17 x S-6532 with the respective susceptibilities of 7.81 and 10.0. Resistances of progenies with a different level of total gossypol to *T. basicola* were also evaluated in the field and no correlation of susceptibility with the total gossypol was observed.

In the study with the previous two pathogens, the Uzbek varieties were more resistant than the American lines. This was not true in the case of *X. malvacearum D.* The BC_3S_1-47-8-1-17 parent was more resistant than any of the Uzbek varieties in both the spring and autumn, and the BC_3S_1-47-8-1-15 was more resistant in the spring

(Tables 5 and 6). This resistance was retained in F_5 progeny BC_3S_1-47-8-1-17 x S-6524 that exhibited the >90% (+)-gossypol trait. In both the spring and autumn, the remaining progeny with the >90% (+)-gossypol seed trait were more susceptible than those exhibiting the 70-80% (+)-gossypol seed trait. Among the parents, the low total gossypol (0.35%) accession BC_3S_1-47-8-1-17, was most resistant to *X. malvacearum D.* Again, there was no observed correlation between total seed gossypol and resistance to *X. malvacearum D.* in the F_5 crosses.

Table 1. Susceptibility of parents and F5 progeny to *Rhizoctonia solani* with different percentages of (+)-gossypol (Spring 2011).

No.	Parents and Crosses	(+)-G %	Total G %	M±m	σ	V
1	S-6524	70.3	1.05	6.56 ± 1.2	2.15	32.7
2	S-6530	77.0	0.54	7.80 ± 2.8	4.89	62.8
3	S-6532	75.0	0.51	2.09 ± 0.8	1.39	66.6
4	BC_3S_1-47-8-1-17	93.3	0.35	22.1 ± 2.3	4.05	18.3
5	BC_3S_1-1-6-3-15	93.3	0.42	9.02 ± 0.4	0.75	8.31
6	$F_5BC_3S_1$-47-8-1-17 x S-6524	77.6	1.20	12.2 ± 0.3	0.59	4.91
7	$F_5BC_3S_1$-47-8-1-17 x S-6524	91.1	0.87	11.2 ± 2.3	4.12	36.9
8	$F_5BC_3S_1$-47-8-1-17 x S-6530	74.4	1.35	20.2 ± 4.5	7.90	39.0
9	$F_5BC_3S_1$-47-8-1-17 x S-6530	91.8	0.46	15.5 ± 2.1	3.75	24.1
10	$F_5BC_3S_1$-47-8-1-17 x S-6532	78.4	0.79	5.43 ± 0.9	1.65	30.4
11	$F_5BC_3S_1$-47-8-1-17 x S-6532	91.8	2.03	15.6 ± 4.2	7.30	46.5
12	$F_5BC_3S_1$-1-6-3-15 x S-6524	74.5	1.45	6.00 ± 0.4	0.80	13.3
13	$F_5BC_3S_1$-1-6-3-15 x S-6524	90.0	1.36	17.0 ± 4.5	7.95	46.7
14	$F_5BC_3S_1$-1-6-3-15 x S-6530	77.3	1.23	17.5 ± 5.3	9.25	52.7
15	$F_5BC_3S_1$-1-6-3-15 x S-6530	90.8	1.20	9.77 ± 2.7	4.83	49.4
16	$F_5BC_3S_1$-1-6-3-15 x S-6532	78.0	1.64	9.87 ± 0.1	0.34	3.45
17	$F_5BC_3S_1$-1-6-3-15 x S-6532	91.0	0.56	9.08 ± 2.7	4.82	53.1

Table 2. Susceptibility of parents and F5 progeny to *Rhizoctonia solani* with different percentages of (+)-gossypol (Autumn 2011).

No.	Parents and Crosses	(+) gossypol, %	total gossypol, %	M±m	σ	V
1	S-6524	70.3	1.05	6.71 ± 1.0	1.88	28.1
2	S-6530	77.0	0.54	3.22 ± 0.6	1.01	31.5
3	S-6532	75.0	0.51	4.50 ± 1.1	1.87	41.6
4	BC_3S_1-47-8-1-17	93.3	0.35	3.49 ± 0.6	1.05	30.2
5	BC_3S_1-1-6-3-15	93.3	0.42	8.32 ± 0.6	1.02	12.3
6	$F_5BC_3S_1$-47-8-1-17 x S-6524	77.6	1.20	2.70 ± 0.4	0.74	27.4
7	$F_5BC_3S_1$-47-8-1-17 x S-6524	91.1	0.87	15.1 ± 2.2	3.79	25.2
8	$F_5BC_3S_1$-47-8-1-17 x S-6530	74.4	1.35	2.82 ± 0.6	1.08	38.4
9	$F_5BC_3S_1$-47-8-1-17 x S-6530	91.8	0.46	5.87 ± 1.2	2.02	34.4
10	$F_5BC_3S_1$-47-8-1-17 x S-6532	78.4	0.79	3.91 ± 2.3	3.92	100.0
11	$F_5BC_3S_1$-47-8-1-17 x S-6532	91.8	2.03	15.0 ± 2.4	4.20	28.0
12	$F_5BC_3S_1$-1-6-3-15 x S-6524	74.5	1.45	8.12 ± 1.3	2.26	27.8
13	$F_5BC_3S_1$-1-6-3-15 x S-6524	90.0	1.36	11.3 ± 1.5	2.60	23.0
14	$F_5BC_3S_1$-1-6-3-15 x S-6530	77.3	1.23	12.8 ± 0.7	1.25	9.79
15	$F_5BC_3S_1$-1-6-3-15 x S-6530	90.8	1.20	5.61 ± 4.7	8.18	1.45
16	$F_5BC_3S_1$-1-6-3-15 x S-6532	78.0	1.64	8.71 ± 1.8	3.17	36.4
17	$F_5BC_3S_1$-1-6-3-15 x S-6532	91.0	0.56	12.4 ± 2.1	3.59	28.9

Table 3. Susceptibility of parents and F5 progeny to *Thielaviopsis basicola* with different percentages of (+)-gossypol (Spring 2011).

No.	Parents and Crosses	(+) gossypol, %	total gossypol, %	M±m	σ	V
1	S-6524	70.3	1.05	13.7 ± 4.8	8.45	61.5
2	S-6530	77.0	0.54	8.30 ± 3.6	6.40	77.1
3	S-6532	75.0	0.51	3.29 ± 0.7	1.29	39.3
4	BC_3S_1-47-8-1-17	93.3	0.35	10.1 ± 0.7	1.30	12.7
5	BC_3S_1-1-6-3-15	93.3	0.42	3.27 ± 1.0	1.88	57.5
6	$F_5BC_3S_1$-47-8-1-17 x S-6524	77.6	1.20	6.00 ± 2.8	4.89	81.5
7	$F_5BC_3S_1$-47-8-1-17 x S-6524	91.1	0.87	10.2 ± 1.4	2.44	23.7
8	$F_5BC_3S_1$-47-8-1-17 x S-6530	74.4	1.35	11.2 ± 1.5	2.75	24.4
9	$F_5BC_3S_1$-47-8-1-17 x S-6530	91.8	0.46	3.66 ± 0.2	0.51	13.9
10	$F_5BC_3S_1$-47-8-1-17 x S-6532	78.4	0.79	7.29 ± 1.5	2.59	35.6
11	$F_5BC_3S_1$-47-8-1-17 x S-6532	91.8	2.03	3.96 ± 0.4	0.85	21.4
12	$F_5BC_3S_1$-1-6-3-15 x S-6524	74.5	1.45	5.50 ± 0.9	1.69	30.9
13	$F_5BC_3S_1$-1-6-3-15 x S-6524	90.0	1.36	2.69 ± 0.7	1.33	49.6
14	$F_5BC_3S_1$-1-6-3-15 x S-6530	77.3	1.23	14.6 ± 1.6	2.79	19.2
15	$F_5BC_3S_1$-1-6-3-15 x S-6530	90.8	1.20	5.93 ± 1.8	3.25	54.7
16	$F_5BC_3S_1$-1-6-3-15 x S-6532	78.0	1.64	8.31 ± 2.4	4.17	50.1
17	$F_5BC_3S_1$-1-6-3-15 x S-6532	91.0	0.56	10.1 ± 0.8	1.50	14.8

Table 4. Susceptibility of parents and F5 progeny to *Thielaviopsis basicola* with different percentages of (+)-gossypol (Autumn 2011).

No.	Parents and Crosses	(+) gossypol, %	total gossypol, %	M±m	σ	V
1	S-6524	70.3	1.05	6.82 ± 1.3	2.40	35.2
2	S-6530	77.0	0.54	5.40 ± 0.5	0.97	17.9
3	S-6532	75.0	0.51	3.69 ± 0.9	1.57	42.5
4	BC_3S_1-47-8-1-17	93.3	0.35	5.82 ± 0.5	0.97	16.6
5	BC_3S_1-1-6-3-15	93.3	0.42	8.69 ± 2.1	3.81	43.8
6	$F_5BC_3S_1$-47-8-1-17 x S-6524	77.6	1.20	1.82 ± 7.0	0.12	6.68
7	$F_5BC_3S_1$-47-8-1-17 x S-6524	91.1	0.87	7.81 ± 0.1	0.28	3.58
8	$F_5BC_3S_1$-47-8-1-17 x S-6530	74.4	1.35	7.50 ± 1.3	2.30	30.6
9	$F_5BC_3S_1$-47-8-1-17 x S-6530	91.8	0.46	2.28 ± 0.2	0.35	15.5
10	$F_5BC_3S_1$-47-8-1-17 x S-6532	78.4	0.79	4.84 ± 1.6	2.86	59.7
11	$F_5BC_3S_1$-47-8-1-17 x S-6532	91.8	2.03	10.0 ± 3.5	6.18	61.7
12	$F_5BC_3S_1$-1-6-3-15 x S-6524	74.5	1.45	3.00 ± 0.5	0.92	30.6
13	$F_5BC_3S_1$-1-6-3-15 x S-6524	90.0	1.36	9.57 ± 0.7	1.23	12.9
14	$F_5BC_3S_1$-1-6-3-15 x S-6530	77.3	1.23	4.91 ± 0.6	1.08	21.9
15	$F_5BC_3S_1$-1-6-3-15 x S-6530	90.8	1.20	2.33 ± 0.2	0.50	21.4
16	$F_5BC_3S_1$-1-6-3-15 x S-6532	78.0	1.64	5.69 ± 2.2	3.83	67.4
17	$F_5BC_3S_1$-1-6-3-15 x S-6532	91.0	0.56	5.92 ± 3.7	6.42	1.08

Table 5. Susceptibility of parents and F5 progeny to *Xanthomonas malvacearum* with different percentages of (+)-gossypol (Spring 2011).

No.	Parents and Crosses	(+) gossypol, %	total gossypol, %	M±m	σ	V
1	S-6524	70.3	1.05	21.8 ± 1.0	1.85	8.49
2	S-6530	77.0	0.54	47.9 ± 0.0	21.1	44.2
3	S-6532	75.0	0.51	24.6 ± 1.6	2.80	11.4
4	BC_3S_1-47-8-1-17	93.3	0.35	6.80 ± 0.4	0.79	11.7
5	BC_3S_1-1-6-3-15	93.3	0.42	10.3 ± 0.2	0.40	3.88
6	$F_5BC_3S_1$-47-8-1-17 x S-6524	77.6	1.20	6.83 ± 0.8	1.45	21.2
7	$F_5BC_3S_1$-47-8-1-17 x S-6524	91.1	0.87	5.53 ± 0.1	0.15	2.76
8	$F_5BC_3S_1$-47-8-1-17 x S-6530	74.4	1.35	15.4 ± 0.8	1.45	9.37
9	$F_5BC_3S_1$-47-8-1-17 x S-6530	91.8	0.46	22.2 ± 2.2	3.86	17.5
10	$F_5BC_3S_1$-47-8-1-17 x S-6532	78.4	0.79	6.90 ± 0.7	1.29	18.8
11	$F_5BC_3S_1$-47-8-1-17 x S-6532	91.8	2.03	19.8 ± 0.4	0.85	4.28
12	$F_5BC_3S_1$-1-6-3-15 x S-6524	74.5	1.45	7.83 ± 1.7	3.05	38.9
13	$F_5BC_3S_1$-1-6-3-15 x S-6524	90.0	1.36	22.4 ± 3.0	5.25	23.3
14	$F_5BC_3S_1$-1-6-3-15 x S-6530	77.3	1.23	3.83 ± 1.0	1.75	45.6
15	$F_5BC_3S_1$-1-6-3-15 x S-6530	90.8	1.20	17.2 ± 1.1	2.00	11.6
16	$F_5BC_3S_1$-1-6-3-15 x S-6532	78.0	1.64	4.83 ± 0.1	0.15	3.16
17	$F_5BC_3S_1$-1-6-3-15 x S-6532	91.0	0.56	12.1 ± 2.3	4.15	34.1

Table 6. Susceptibility of parents and F5 progeny to *Xanthomonas malvacearum* with different percentages of (+)-gossypol (Autumn 2011).

No.	Parents and Crosses	(+) gossypol, %	total gossypol, %	M±m	σ	V
1	S-6524	70.3	1.05	14.1 ± 0.4	0.75	5.33
2	S-6530	77.0	0.54	16.4 ± 2.0	3.59	21.9
3	S-6532	75.0	0.51	15.9 ± 0.1	5.00	0.31
4	BC_3S_1-47-8-1-17	93.3	0.35	12.9 ± 0.4	0.70	5.41
5	BC_3S_1-1-6-3-15	93.3	0.42	14.9 ± 4.0	7.00	46.9
6	$F_5BC_3S_1$-47-8-1-17 x S-6524	77.6	1.20	6.40 ± 0.3	0.50	7.81
7	$F_5BC_3S_1$-47-8-1-17 x S-6524	91.1	0.87	9.60 ± 2.2	3.90	40.6
8	$F_5BC_3S_1$-47-8-1-17 x S-6530	74.4	1.35	9.83 ± 2.0	3.61	36.7
9	$F_5BC_3S_1$-47-8-1-17 x S-6530	91.8	0.46	11.6 ± 1.0	1.75	15.4
10	$F_5BC_3S_1$-47-8-1-17 x S-6532	78.4	0.79	11.6 ± 2.0	3.79	32.7
11	$F_5BC_3S_1$-47-8-1-17 x S-6532	91.8	2.03	17.3 ± 2.2	3.80	21.9
12	$F_5BC_3S_1$-1-6-3-15 x S-6524	74.5	1.45	7.09 ± 0.7	1.20	16.9
13	$F_5BC_3S_1$-1-6-3-15 x S-6524	90.0	1.36	30.1 ± 1.4	2.45	8.13
14	$F_5BC_3S_1$-1-6-3-15 x S-6530	77.3	1.23	13.7 ± 1.3	2.25	16.3
15	$F_5BC_3S_1$-1-6-3-15 x S-6530	90.8	1.20	23.5 ± 2.9	5.05	21.4
16	$F_5BC_3S_1$-1-6-3-15 x S-6532	78.0	1.64	9.36 ± 8.8	0.15	1.63
17	$F_5BC_3S_1$-1-6-3-15 x S-6532	91.0	0.56	22.7 ± 3.8	6.69	29.9

Resistance of Varieties to *Heliothis armigera*

We studied the influences of total and (+)-gossypol percentages in seed to insect resistance among several local cotton varieties and the U.S. accessions BC_3S_1-47-8-1-17 and BC_3S_1-1-6-3-15 (Table 7). No dependence was observed between the (+)-gossypol percentage in seed and resistance to *Heliothis armigera*. For example, local varieties S-6524, S-6530 and S-6532 which have a rather high percent of (+)-gossypol in seeds (70.0%; 67.1% and 70.9%, respectively), were more susceptible in comparison to other varieties. Plant damage values for these three cultivars were 19.1%; 21.4 % and 25.9 %, respectively. However, the U.S. accession BC_3S_1-1-6-3-15 with 93.5% (+)-gossypol was highly susceptible to the *Heliothis armigera* (23.5% damaged), but the other U.S. accession (BC_3S_1-47-8-1-17) with 93.3% (+)-gossypol in the seed showed little damage (11.6 % damaged). Similarly, total gossypol in seed was also a poor predictor of resistance to *H. armigera*. Thus, the data shows independence between percent (+)-gossypol and total gossypol in seed and resistance to *H. armigera*. Notably, the high seed gossypol varieties L-10/04, Turon and Bukhara-8 showed good resistance to *H. armigera* Hb.

Table 7. Susceptibility of cotton varieties, lines and USA accessions to *Heliothis armigera* (%).

No.	Cotton Varieties, Lines and Accessions	(+) –Gossypol Seed (%)	Total Gossypol Seed (%)	Damage (%)
1	Omad	58.8	1.78	16.9
2	S– 6524	70.0	1.05	19.1
3	S – 6530	67.1	1.08	21.4
4	S – 6532	70.9	1.78	25.9
5	S – 2610	53.8	1.64	17.7
6	S – 8288	58.1	1.85	12.1
7	L – 10/04	69.5	1.97	0
8	L – 842	59.4	1.13	15.2
9	Turon	49.3	2.26	7.5
10	Bukhara – 8	56.3	2.05	8.6
11	BC_3S_1-47-8-1-17	93.3	1.73	11.6
12	BC_3S_1 -1-6-3-15	93.5	1.70	23.5

Conclusion

In comparing all crosses with the three pathogens investigated, the plants exhibiting the >90% (+)-gossypol trait resulting from the BC_3S_1-47-8-1-17 x S-6530 cross gave the best resistance to all pathogens in both spring and autumn with the exception of the spring with *X. malvacearum D.* The susceptibility of the progeny was better than the S-6530 parent, but the BC_3S_1-47-8-1-17 x S-6524 provided a less susceptible progeny. Nevertheless, even in this case, the progeny from the BC_3S_1-47-8-1-17 x S-6530 cross was equally resistant to this pathogen compared to any of the Uzbek parents. No correlation of resistance was observed between the percentage of (+)-gossypol in seed with resistance to total *H. armigera* Hb. The same was true regarding total seed gossypol.

The overall results are encouraging in that it should be possible to develop plants with acceptable levels of resistance to these important pathogens as well as to *H. armigera* Hb, and retain a high percentage of (+)-gossypol in seed. Additional years of testing will be required to further assess these findings.

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References

Belousov M.A., Z.C. Tursunxodjaev, M.P. Mednis , I.M. Madraimov, V.P. Kondratyk, A.A. Raximbaev, and A.P. Kenzer. 1973. Methods of field and vegetative experiments with cotton in irrigation conditions. Tashkent, pp. 223.

Bottger, G.T., Patana, R. 1966. Growth, Development, and Survival of Certain Lepidoptera Fed Gossypol in the Diet, *J. Econ. Etomol.* 59:1166-1168.

Bottger, G. T., Sheehan, E. T., Lukefahr, M. J. 1964. Relation of gossypol content of cotton plants to insect resistance. *J. Econ. Entomol.* 57*:*283-285.

Cass, Q. B., E. Tiritan, S.A. Matlin, E.C. Freire. 1991. Gossypol enantiomer ratios in cotton seeds. *Phytochemistry* 30:2655–2657.

Dospekhov B.A. 1985. Metodika polevogo opita. Agropromizdat, Moscow, Russia pp. 351.

Jaroszewski, J.W., T. Strom-Hansen, L.L. Hanson. 1992. Optical stability of gossypol. *Chirality* 4:216–221.

Khasanov, O., Babanazarov A. 1976. The estimation *Rizoctania solani*. *J. Cotton Growing*, 1976:35.

Namazov, Sh.E,, Yuldosheva, R.A., Marupov, A.I., Ishanqulova, M., Bell, A., Stipanovic, R. 25th Proceedings of the International Conference "Perspectives of using of biological methods of Plant Protection from harmful organisms in agriculture, December, 2008, Tashkent, Uzbekistan.25:327-330.

Naumov N.A. The methods of microscopically in fitopathological researches. Leningrad,1932.

Puckhaber, L.S., Dowd, M.K., Stipanovic, R.D., Howell, C.R. 2002. Toxicity of (+)- and (-)-gossypol to the plant pathogen, *Rhizoctonia solani*. *J. Agri. Food Chem.* 50:7017-7021.

Shvetsova, L.P., Em E.E. 1991. Methods of estimation resistance of cotton varieties and accessions to bollworm. Tashkent.

Stipanovic, R.D., J. Lopez, M.K.Dowd, L.S. Puchaber, and S.E.Duke. 2006. Effect of racemic and (+) and (-) -gossypol on the survival and development of *Helicoverpa zea* larvae. *J. Chem. Ecol*. 32:959-968.

Stipanovic, R.D., Puchaber, L.S., Bell, A.A., Percival, A.E., Jacobs, J. 2005. Occurrence of (+)-and (-)-gossypol in wild species of cotton and in *Gossypium gric.Food Chem.hirsutum marie galante* (Watt) Hutchinson. *J. Agric. Food Chem*.

Wu, D.F.,Y.W.Yu,Z.M..Tang, M.Z.Wang. 1986. Pharmocoenetics of (±)-,(+)-, and (-)-gossypol in humans and dogs. *Clin.Pharmacol. Ther*. 39:613-618.

Yang, W.-H., Ma L.-H., Zhu H.-Q., Xiang S.-K. 1999. Effects of different gossypol enantiomers on growth and development of cotton bollworm (*Helicoverpa armigera*) and Fusarium wilt. *Acta Gossypii Sinica*, 11:31-34.

Yildirim-Aksoy, M., Lim C., Dowd M.K., Wan P.J., Klesius P.H., Shoemaker C. 2004. *In vitro* inhibitory effects of gossypol from gossypol-acetic acid, and (+)- and (-)-isomers of gossypol on the growth of *Edwardsiella ictaluri*. *J. Appl. Microbiol*. 97:87-92.