1297 Initial Materials for Cotton Varieties Development with (+) Gossypol Level

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Abstract

The results of our research showed that the Uzbek cotton cultivars that we studied did not exhibit great differences in the ratio of (+)- to ( ) gossypol. This is in contrast to that found in American cotton cultivars. Among the Uzbek accessions with a high (+)-gossypol, those cultivars with the highest level of (+)-gossypol were selected for additional crosses with plants that exhibited high levels of (+)-gossypol in the seed. Among these studied accessions, a strong differentiation was observed regarding resistance to *Verticillium dahliae Kleb*.

Keywords: *Cottonseed, cultivar, accession, hybrids, (-) and (+)-gossypol, morphological and economic-value characteristics, wilt, resistance.*

Introduction

Cottonseed is a major source of vegetative oil. In addition, the meal that results after the oil is removed provides a high protein concentrate that represents a product with potentially high economic value. Cottonseed oil is the second leading vegetable oil world wide following soybean. Cottonseeds consists 20-25 % oil by weight. Besides oil, cottonseed provides flour (35-40%), lint (9%) and mill cake (26%), and only 4% is wasted (Gubanov et al., 1986). One of the problems that limit cottonseed utilization is the presence of glands in the seed that contain gossypol, which is toxic to animals, especially non-ruminants.

Gossypol occurs as a mixture of enantiomers, which are termed (+) gossypol and (-)-gossypol. The ratio of these enantiomers varies from 98:2 to 31:69 in seed (Cass et al., 1991; Percy et al., 1996; Stipanovic et al., 2005). These results have been confirmed by Dowd et al. (Barbara et al., 2005). Within widely distributed commercial cultivars of *Gossypium hirsutum*, the ratio of (+)- to (-)-gossypol is approximately 3:2. It has been shown that ( ) gossypol is more biologically active than (+)-gossypol (Matlin et al., 1985, Wu et al., 1986, Lindberg et al., 1987), and the (+)-enantiomer shows little if any toxicity in chickens (Bailey et al., 2000).

Taking into account these research findings, the objective of this study was investigating the possibility of transferring the high gossypol seed trait into local Uzbek cultivars from American accessions while retaining important agronomic attributes and wilt resistance.

MATERIALS AND METHODS

Plant Breeding. Alois A. Bell, USDA-ARS, provided six accessions for crossing with Uzbek cultivars and lines. Specific U.S. accessions included BC-8 PL-14, BC-7 PL-15, BC-2 PL-19, BC-4 PL-10, BC-4 PL-12, and 6-BC-8 PL-15. These were crossed with the following Uzbek cultivars and lines: Omad, Bukhara-8, 108-F, Turon, S-5621, S-2609, S-6524, L-8, and F_1 hybrids from crossing with the six American accessions mentioned above.

The experiments were conducted in both quarantine nursery since 2004 and greenhouses but in the field since 2005. The temperature in greenhouse is supported in the following parameters: up to bud formation in the afternoon 34-36^{0}C, at night-18-20^{0}C, at bud formation, flowerings and fruiting - in the afternoon 26-28^{0}C, at night 18-20^{0}C, at maturing phase in the afternoon-34-36^{0}C, at night 25-28^{0}C. The experimental plots have a typical serozem soils with small maintenance of humus (up to 1,0 %) and deep ground water level (7-8 m). According to long-term data precipitation per year comes on the average 360 mm^3, mainly at the autumn-winter-spring period. The period of mass fruiting of cotton is marked by a minimum quantity of precipitation, low content of air humidity. Crop was spent manually on depth of 4-5 sms, under the scheme 60x25-1. At growing period cotton plants were irrigated 4-5 times on a regular basis annually there were used the annual rate of the following mineral fertilizers: N-240 kg/ha, P_2O_5-160 kg/ha, K_2O- 120 kg/ha.

The following data were observed on the cotton plants: flowering dates, maturation, mass of seedcotton in one boll, plant productivity, and the rest morphological plant description and laboratory analyses of fiber and seed. Chemical analysis for total and (+)- and (-)-gossypol: The total free gossypol and the ratio of (+)- and (-)-gossypol were determined in the flowers and seeds of Uzbek cultivars and in progeny derived from crosses with U.S. lines. These were determined by HPLC methods as previously described by Hron et al. (1999).

Results and Discussions

The total and percent of (+)- and (-)-gossypol for eleven Uzbek cotton cultivars are shown in Table 1. The mean value for (+)-gossypol was 58.4% (± 6.4). Notably, C 6524 and C-6530, which have a similar phenotype, had the highest amount of (+)-gossypol with a 7:3 ratio of (+)- to ( ) gossypol. Turon was unusual in that it contained more (-)-gossypol than (+)-gossypol [i.e., 52.1% ( ) gossypol], which may be a result of its complex origin with participation of various subspecies of cotton {F_5(Deltipine-16, x ssp. morilli) x F_5(Paymaster-266 x ssp. richmondii).

In contrast to the closely spaced ratios of (+)- and (-)-gossypol, the total gossypol content exhibited large differences ranging from 1.08% to 2.35%.

Six accessions received from the U.S. were evaluated for enantiomer ratios during 2004 and 2005 (Tables 2 and 3). Data for 2004 were collected from plants grown at the quarantine nursery. Plants exhibiting the highest levels of seeds (+)-gossypol were selfed and the resulting progeny were grown under greenhouse culture during 2005. As shown in Table 2, in 2004 only six of 37 plants had 81% or greater (+) gossypol in the seed. The average level of (+)-gossypol across the different accessions ranged from 68.0% for BC-7PL-15 to 79.2% for BC-8PL-14. BC-8PL-12 expressed a low standard deviation for seed (+)-gossypol , suggesting homogeneity for this trait among plants within his line, while three accessions, BC-8PL-14, BC-4PL-10, and BC-8PL-15 had standard deviations about three times as great, suggesting that these lines may be heterogeneous and yield to further selection.

Table 3 shows the results from self pollinated plants with the highest level of (+) gossypol in the seed that were observed in 2004. The average (+)-gossypol content increased from 4.0-8.1 % in 2005 in comparison to the previous year and ranged from 72.0-87.3%. In 2005, 28 of 56 plants tested contained 81% or more seed (+)-gossypol. BC-8 PL-14, BC-2 PL-19 and BC-4 PL-10 averaged 87.3, 87.0, and 82% of their total gossypol as (+)-gossypol. BC4PL10 again had a relative high standard deviation for seed (+)-gossypol along with BC-7PL-15, which had the highest standard deviation in 2005 at 13.8.

Significant plant to plant variations exist within the U.S. accessions (Tables 2 and 3) although little variation was detected across accessions. These data suggest that progress could be made in developing genotypes with higher levels of seed (+)-gossypol through pure line selection methods within existing material. Data from 2004 suggest that BC-8PL-14 would be a desirable U.S. accession for individual plant selection while 2005 data suggest that progress could be made with any accession except BC-4PL-12 or BC-8PL-15.

Some morphological and economic-value characteristics of U.S. accessions, Uzbek cultivars and lines, and F_1 hybrids are presented in Table 4. The U.S. accessions matured 13 to 15 days later than the Uzbek cultivar Omad. The growing period of the Uzbek cultivars were between 119-127 days. The longer vegetative period of the U.S. accessions was characterized by an increase of about one sympodial branch height, which would account for about half of the observed delay in maturity. The U.S. accessions also had more monopodium branches.

The height of the main stalk of the Uzbek cultivars varied from 86 to 136 cm, and in the U.S. lines ranged from 95 to 142 cm. Among the U.S. accessions, BC-2 PL-19 was exceptionally short with a height of only 95 cm. The height differences were the result of addition main stem nodes in the U.S. accessions since differences in the length of internodes were not observed. Shorter plants had fewer sympodial branches and a shorter distance between sympodial branches, i.e., fewer main stem nodes and shorter internodes. Similar dates were observed under both field and greenhouse conditions. This illustrates the genetic dependence of this characteristic, and is important for breeding cotton in climates with a shorter growing season.

Boll size, i.e. the average seedcotton mass in one boll, of the Uzbek cultivars and lines was 5.0-6.2 g, and was higher ($LSD_{0,5}$=0,38) than U.S. lines that ranged from 3.1 to 4.5 g. The U.S. BC-4 PL-10 line had the highest seedcotton cotton mass of 4.5 g. The fiber turnout, or % lint, for the U.S. accessions, except BC-7 PL-15 and BC-2 PL-19, were similar ($LSD_{0,5}$=1.06) to those of the Uzbek cultivars and lines. With the exception of BC-7 PL-15, the fiber lengths of the U.S. accessions were inferior ($LSD_{0, 5}$=1.27) to the Uzbek material. Differences between the U.S. and Uzbek cultivars probably originates form the derivation of the U.S. lines from the parental *G. hirsutum marie galante*, which originates from South

America while the Uzbek material originated with a participation of different long and extra long fiber cotton species like *G.barbadense (Bukhara-6), G. hirsutum ssp. punctatum (S-6524)*. In addition, little selection pressure has been applied by U.S. breeders for such traits as boll size since the general acceptance of mechanical harvest in that country.

Table 4 provides data on F_1 hybrids developed by hybridization used of Uzbek and the six U.S. accessions. The duration of growing period changed depending on the parent. Of particular interest was the hybrid between Omad and BC-2 PL-19, which had a growing period that was 2-13 days shorter than in the other hybrids. The longest growing period was the hybrid between L-8 and BC-4 PL-12 (139 days), a case where both parents express a long growing season requirement and so this result was not unexpected. The F_1 of BC-4PL-12 x L-8 produced exceptional fiber length at 38.4 mm, well into the extra long staple range. All other traits were within expected limits.

Analysis for *Verticillium dahliae Kleb.* resistance. The U.S. accessions were evaluated for resistance to the wilt pathogen *Verticillium dahliae* during 2005 (Table 5). Significant differences ($LSD_{0,5}$=0,50) in wilt resistance were noted. The number of infected plants ranged from 18.0 to 60.8%, and between 3.2 and 16.0% of these plants showed high levels of wilt symptoms. Accessions BC-2 PL-19 and BC-4 PL-10 had the highest number of infected plants (60.3 and 46.0%, respectively), and the highest number of plants showing strong wilt symptoms (14.9and 16.0%, respectively). BC-8 PL-14 had the least number of infected plants. The results in 2006 confirmed the susceptibility to Verticillium wilt of the U.S. accessions with high level of seed (+)-gossypol when studied in naturally *V. dahliae* infected soil (Table 6).

The number of plants showing some wilt symptoms in 2006 varied from 70.4% (BC-2 Pl-19) up to 81.2 % (BC-7 Pl-15), with 3.2% of the BC-2 Pl-19 plants showing severe wilt symptoms and 41.5 % of the BC-4 Pl-10 showing severe wilt symptoms.

Wilt resistance of F_2 populatoins: Although the high (+)-gossypol parents are extremely susceptible to *Verticcillium* wilt, data from F_2 populations suggest that these accessions can be used as parents with *Verticcillium* resistant Uzbek strains to produce populations from which to select for *Verticcillium* resistance as well as higher levels of (+)-gossypol in seeds (Table 6). Among all the hybrids, only three crosses had plants with no severe wilt symptoms (i.e., BC-2 Pl-19 x S-2609, BC-4 Pl-10 x Omad and BC-4 Pl-10 x Turon).

Conclusions: It appears that it is possible to select the plants with a high percentage of (+) gossypol content in seed, retaining wilt resistance F_2 populations based on the taken data in 2006. There are determined three combinations (BC-8 Pl-15 x Bukhara-6, BC-8 Pl-15x Omad and BC-2 Pl-19 x L-8), which are wilt resistance and having a high level of (+) gossypol content in seeds. Thus, we recommend for future hybridization to use American accessions with a high percentage of (+)-gossypol level in seed as a fraternal form, but as the maternal ones to use a local wilt resistance accessions.

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Table 1. Gossypol content of Uzbek cotton cultivars and lines, %.

Cultivar and line	(+) enantiomer, %	(-) enantiomer, %	Total gossypol, %
Bukhara-8	55.9	44.1	2.0
Bukhara-6	58.0	42.0	1.5
S-2610	51.1	48.9	1.6
S -6530	67.1	32.1	1.1
S -6524	70.0	30.0	1.0
Denau	62.7	37.3	1.7
Turon	47.9	52.1	2.3
S -8288	55.0	45.0	1.8
Omad	57.2	42.8	1.8
L-842	58.6	41.4	1.1
L-8	58.9	41.1	2.3

$LSD_{0,5}$=0,97 $LSD_{0,5}$=0,82 $LSD_{0,5}$=0,07

Table 2. Variation of level (+)-gossypol content in U.S. accessions, 2004.

U.S. line	Range of (+)-gossypol in seed from individual plants								Average	V^c
	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	$X \pm S^b$	
BC-8 PL-14	-	-	1	2	2	1	1	1	79.2±8.3	10.5
BC-7 PL-15	-	3	-	3	-	-	-	-	68.0±5.5	8.0
BC-2 PL-19	-	-	2	3	-	2	-	-	74.4±6.3	8.4
BC-4 PL-10	1	-	1	1	3	-	-	-	72.2±8.0	11.0
BC-4 PL-12	-	-	4	2	-	-	-	-	69.6±2.5	3.6
BC-8 PL-15	2	2	3	-	-	1	-	-	71.7±7.9	11.0

[b] S is standard deviation.

[c] V is coefficient of variation.

Table 3.Variation of level of (+)-gossypol content of U.S. accessions, 2005.

U.S. line	Range of (+)-gossypol in seed from individual plants								Average	V^c
	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	X± S^b	
BC-8 PL-14	-	-	1	-	1	3	3	-	87.3±6.8	7.7
BC-7 PL-15	-	3	2	-	-	-	1	2	79.9±13.8	17.3
BC-2 PL-19	1	-	1	-	-	4	2	2	87.0±11.0	12.6
BC-4 PL-10	-	4	-	-	-	3	2	1	82.0±12.4	15.1
BC-4 PL-12	3	2	3	-	1	-	1	-	72.0±9.6	13.4
BC-8 PL-15	5	-	-	2	2	-	-	-	70.8±9.4	13.2

[b] S is standard deviation.

[c] V is coefficient of variation.

Table 4. Economic value characteristics of initial materials and F_1 hybrids.

№	Cultivar, accession, hybrid F_1	Main stalk height, cm			First sympodial branch height,cm			Monopodial branches number			Sympodial branches number		
		M±m	S	V%	M±m	S	V%	M±m	S	V%	M±m	S	V%
1	Omad	86.0±3.1	9.9	11.6	4.3 ± 0.3	0.8	19.5	1.3±0.1	0.5	37.2	16.6±1.7	5.5	33.0
2	Bukhara-6	136.0±3.9	18.8	13.8	4.7 ± 0.3	0.8	17.2	0.9±0.2	0.6	63.1	21.6±0.7	2.7	12.6
3	S-6524	130.0±3.8	19.7	15.2	5.5 ± 0.2	0.7	12.9	0.8±0.1	0.4	52.7	21.7±1.3	4.2	19.6
4	BC-8 PL -14	98.5±5.0	31.3	31.7	3.9 ± 0.5	1.7	44.3	0.6±0.3	0.8	40.5	21.3±2.7	8.7	40.7
5	BC-7 PL -15	142.0±4.1	19.2	13.5	6.4 ± 0.3	0.8	13.2	2.5±0.6	1.8	73.6	27.9±1.2	3.7	13.3
6	BC-2 PL -19	95.0±4.3	19.7	20.8	4.7 ± 0.4	1.2	24.7	1.7±0.2	0.7	47.1	19.5±1.1	3.6	18.3
7	BC-4 PL -10	127.0±4.9	31.0	24.4	5.0 ± 0.4	1.1	23.1	1.7±0.4	1.2	78.6	21.3±1.3	3.9	18.7
8	BC-4 PL -12	110.5±4.7	14.8	13.4	5.5 ± 0.7	2.4	43.1	1.5±0.4	1.3	90.3	21.5±1.1	3.4	15.7
9	BC-8 PL -15	106.5±4.9	21.9	20.6	5.4 ± 0.5	1.5	27.9	0.6±0.2	0.7	76.5	21.1±1.8	5.6	26.6
10	BC-8 PL -14 x Bukhara-6	103.5±4.2	22.7	21.9	5.2 ± 0.9	2.9	56.5	0.8±0.4	1.2	83.7	19.4±1.2	3.9	20.1
11	BC-7 PL -15 x 108-F	120.3±5.0	18.3	15.2	3.9 ± 0.7	2.1	54.7	1.2±0.2	0.8	65.1	23.6±0.8	2.6	11.3
12	BC-2 PL -19 x Omad	96.8±4.8	16.3	16.9	4.8 ± 0.3	0.9	19.1	1.1±0.2	0.7	67.1	20.9±0.8	2.7	12.9
13	BC-4 PL -10 x Turon	112.4±4.5	14.3	12.8	4.2 ± 0.5	1.5	36.9	1.1±0.2	0.7	67.1	21.5±0.7	2.2	10.3
14	BC-4 PL -12 x L-8	102.8±4.8	22.9	27.1	4.8 ± 0.3	0.9	19.1	0.8±0.2	0.8	98.6	17.9±1.2	3.7	20.8
15	BC-8 PL -15 x S-5621	115.5±4.3	16.7	14.4	5.1 ± 0.3	0.9	17.2	1.8±0.2	0.8	43.8	21.9±0.6	2.0	9.2
16	BC-4 PL -10 x S-2609	118.4±4.1	25.8	21.8	5.0 ± 0.4	1.1	23.1	0.9±0.3	0.9	97.3	21.6±1.6	4.9	23.0
17	BC-4 PL -10 x S-6524	127.2±4.1	13.1	10.3	4.0 ± 0.5	1.6	40.8	1.4±0.3	0.8	60.2	22.8±0.7	2.3	10.3

$LSD_{0.5}$=2.28 $LSD_{0.5}$=0.28 $LSD_{0.5}$=0.35 $LSD_{0.5}$=0.92

Table 4. Continued

№	Cultivar, accession, hybrid F_1	Growing period, days			Mass of one boll, g.			Fiber turnout, %			Fiber length, mm		
		M±m	S	V%	M±m	S	V%	M±m	S	V%	M±m	S	V%
1	Omad	M±m	2.2	1.8	5.1±0.2	0.4	7.4	38.9±1.4	2.4	6.1	33.6±0.7	1.2	3.6
2	Bukhara-6	119.0±0.7	5.2	4.1	6.2±0.6	1.0	16.2	37.6±1.4	2.4	6.4	33.5±1.2	2.0	6.1
3	S-6524	126.6±1.6	3.3	2.6	5.0±0.1	0.2	4.0	36.4±0.5	0.9	2.7	34.1±0.5	0.8	2.5
4	BC-8 PL -14	126.8±1.0	2.7	2.0	3.4±0.2	0.6	18.1	34.1±1.3	3.4	10.1	27.5±1.6	4.3	16.5
5	BC-7 PL -15	135.2±0.9	2.8	2.1	3.4±0.3	0.7	19.3	31.5±1.3	3.5	11.1	34.1±0.7	2.0	6.0
6	BC-2 PL -19	133.8±0.9	3.7	2.8	3.6±0.2	0.5	13.9	33.8±1.2	3.9	11.5	31.9±0.8	2.8	8.7
7	BC-4 PL -10	132.8±1.2	5.9	4.4	4.5±0.3	0.9	19.7	35.4±1.2	3.9	10.9	32.2±0.7	2.3	7.3
8	BC-4 PL -12	135.3±1.9	4.8	3.6	3.6±0.2	0.7	17.4	37.9±0.8	2.7	7.1	31.2±0.5	1.6	5.3
9	BC-8 PL -15	132.6±1.5	4.1	3.1	3.1±0.2	0.7	21.6	38.7±1.4	4.6	11.8	30.6±0.5	1.8	5.9
10	BC-8 PL -14 x Bukhara-6	131.7±1.3	4.3	3.2	3.8±0.2	0.5	13.1	37.2±1.7	4.2	11.2	31.5±0.6	1.9	6.3
11	BC-7 PL -15 x 108-F	133.4±1.4	4.8	3.7	4.2±0.2	0.6	15.4	36.2±0.5	1.8	5.1	29.4±0.4	1.6	5.4
12	BC-2 PL -19 x Omad	130.9±1.5	5.2	4.1	4.5±0.2	0.6	13.8	39.0±1.1	3.6	9.1	30.2±0.8	2.9	9.5
13	BC-4 PL -10 x Turon	126.3±1.7	3.9	2.9	4.2±0.1	0.5	12.5	41.2±0.6	2.2	5.4	31.4±0.9	3.6	9.6
14	BC-4 PL -12 x L-8	132.2±1.2	5.3	4.8	4.0±0.2	0.8	19.1	31.0±1.1	3.3	10.6	38.5±0.4	1.4	3.8
15	BC-8 PL -15 x S-5621	139.1±1.4	3.7	3.3	4.2±0.2	0.6	13.8	40.6±1.2	4.1	10.2	31.7±0.8	2.7	8.6
16	BC-4 PL -10 x S-2609	127.9±1.2	3.8	2.8	5.3±0.2	0.8	16.9	35.2±1.2	4.0	11.4	33.1±0.7	2.7	8.4
17	BC-4 PL -10 x S-6524	128.2±1.4	4.1	3.3	4.1±0.1	0.5	12.4	36.4±0.7	2.3	6.2	30.9±0.6	1.9	6.4

$LSD_{0.5}$=1.00 $LSD_{0.5}$=0.38 $LSD_{0.5}$=1.06 $LSD_{0.5}$=1.27

Table-5.Parameters of U.S. accessions for wilt resistance, 2005.

№	**Accession**	**In general degree, %**	**In strong degree, %**
1	**BC-8 PL-14**	**18.0**	**9.6**
2	**BC-7 PL-15**	**21.7**	**6.6**
3	**BC-2 PL-19**	**60.8**	**14.9**
4	**BC-4 PL-10**	**46.0**	**16.0**
5	**BC-4 PL-12**	**30.6**	**3.2**
6.	**BC-8 Pl-15**	**31.7**	**8.1**

$LSD_{0.5}$=0.50 $LSD_{0.5}$=0.56

Table-6.Parameters of US accessions and hybrids F_2 for wilt resistance.

№	Accession and hybrid	In general degree, %	In strong degree, %
1	BC-8 PL-14	74.4	46.2
2	BC-7 PL-15	86.7	73.5
3	BC-2 PL-19	84.9	72.9
4	BC-4 PL-10	69.4	29.3
5	BC-4 PL-12	30.6	3.2
6.	BC-8 Pl-15	63.3	32.1
7	BC-8 PL-14 x Bukhara-6	35.1	10.9
8	BC-8 PL-14 x 108-F	33.2	15.3
9	BC-8 PL-14 x Turon	33.3	14.2
10	BC-8 PL-14 x S-5621	52.6	15.7
11	BC-8 PL-14 x S-6524	26.8	38.4
12	BC-7 PL-15 x Bukhara-6	43.9	40.5
13	BC-8 PL-14 x 108-F	41.6	17.6
14	BC-2 PL-19 x 108-F	60.0	25.0
15	BC-7 PL-15 x Omad	55.4	20.9
16	BC-7 PL-15 x Turon	92.3	100.0
17	BC-7 PL-15 x L-8	60.9	65.7
18	BC-7 PL-15 x S-5621	37.4	18.4
19	BC-7 PL-15 x S-2609	45.8	27.1
20	BC-7 PL-15 x S-6524	70.8	40.0
21	BC-2 PL-19 x Bukhara-6	50.0	50.0
22	BC-2PL-19 x 108-F	100.0	100.0
23	BC-2 PL-19 x Omad	92.9	92.9
24	BC-8 PL-15 x Bukhara-6	54.0	44.4
25	BC-2 PL-19 x Turon	93.7	82.1
26	BC-8 PL-15 x S-2609	87.5	50.0
27	BC-2 PL-19 x S-2609	61.2	29.0

Table 6. Continued

№	Accession and hybrid	In general degree, %	In strong degree, %
28	BC-2 PL-19 x S-6524	35.3	11.7
29	BC-4 PL-10 x Bukhara-6	66.5	36.7
30	BC-4 PL-10 x 108-F	42.7	30.5
31	BC-4 PL-10 x Omad	23.0	0.0
32	BC-4 PL-10 x Turon	66.6	0.0
33	BC-4 PL-10 x L-8	60.1	45.1
34	BC--4PL-10 x S-5621	33.8	22.5
35	BC-4 PL-10 x S-2609	51.3	40.9
36	BC-4 PL-10 x S-6524	39.4	33.9
37	BC-4 PL-12 x Bukhara-6	49.2	25.0
38	BC-4 PL-12 x 108-F	57.8	21.8
39	BC-4 PL-12 x Omad	49.7	32.5
40	BC-4 PL-12 x Turon	48.2	33.4
41	BC-4 PL-12 x L-8	47.7	24.3
42	BC-4 PL-12 x C-5621	58.3	34.3
43	BC-4 PL-12 x S-2609	67.7	51.1
44	BC-4 PL-12 x S-6524	44.9	32.4
45	BC-8 PL-15 x 108-F	75.2	77.4
46	BC-8 PL-15 x Omad	53.7	47.4
47	BC-8 PL-15 x Turon	40.0	33.4
48	BC-8 PL-15 x L-8	55.3	24.1
49	BC-8 PL-15 x S-5621	68.2	37.8
50	BC-8 PL-15 x S-2609	68.1	35.9
51	BC-8 PL-15 x S-6524	58.2	54.1

$LSD_{0.5}$=0.15 $LSD_{0.5}$=0.33