

1 **Combining abilities for maize stem antibiosis, yield loss and yield under infestation and**
2 **no infestation with pink stem borer**

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1 **Abstract**

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The pink stem borer (*Sesamia nonagrioides* Lef.) is the main pest of maize (*Zea mays* L.) in northwestern Spain. Little is known about combining ability for antibiosis and tolerance to this pest. Therefore, the objectives of this work was the estimation of general combining ability (GCA), specific combining ability (SCA) and reciprocal effects (R) for stem damage traits, yield and yield loss, using a complete diallel of ten inbreds, and to determine the most useful trait for evaluating the level of defense to pink stem borer. The diallel design was evaluated for two years for stem damage traits, yield loss, and for yield under two conditions, infestation with *Sesamia nonagrioides* and no infestation. For all stem damage traits, general combining ability was significant, while specific combining ability and reciprocal effects were not significant. This indicated that, for this set of inbreds, only additive effects were important for stem antibiosis. GCA and SCA effects were significant, in at least a trial, for yield under both infestation conditions and for yield loss. R effects were significant for yield of infested and no infested plants in 1995. The lack of concordance among lines that exhibited the most favorable GCA effects for stem antibiosis, yield loss, and yield under infestation conditions and the low correlation coefficient between SCA effects for yield under infestation and no infestation conditions showed that yield under infestation conditions is the best trait for evaluating the level of defense against pink stem borer attack. A interpopulational recurrent selection program for yield under infestation conditions appears as the most efficient program to improve the defense level against pink stem borer attack.

Key words: *Sesamia nonagrioides*, stem borer, antibiosis, yield loss, combining ability.

Introduction

Insect pests can cause high yield losses at different phenological stages of maize. The most important pest of maize in temperate areas of the northern hemisphere is the European corn borer (*Ostrinia nubilalis* Hbn), but in southern Europe the pink stem borer also causes significant damage to maize. Specifically, in the northwest of Spain, the pink stem borer is the main pest of maize (Cordero et al., 1998).

Sesamia nonagrioides is a tropical moth (Fam. *Noctuidae*) and temperatures below 0°C limit the population levels (Galichet, 1982). In most of its area it has two generations per year, but it can reach even four generations per year. Most of the larvae development takes place into the maize plant and it can provoke lodging stem, ear drop and direct yield losses, but *Sesamia nonagrioides* prefers attacking stems rather than ears (Cordero et al., 1998). The yield losses could reach up to 30% of yield (Larue, 1984).

One of the most promising methods for controlling an insect pest in the overall context of integrated pest control is to grow insect resistant cultivars (Ortega et al., 1980; Pathak, 1991). To start a breeding program to increase the level of defense of maize to *Sesamia nonagrioides* it is necessary to know the different mechanisms of defense against this insect and to determine the transmission of each mechanism from the original plants to cultivars (Pathak, 1991). The mechanisms of defense have been classified into three groups, namely antixenosis, antibiosis, and tolerance (Painter, 1951). Antixenosis reduces the probability of contact between parasites and plants. Antibiosis is the ability of the plant to reduce or stop the growth and/or development of the parasite. Tolerance is the mechanism by which plants reduce the extent of damage per unit parasite present. Therefore, to detect differences in tolerance among genotypes it is necessary to determine the amount of yield reduction per unit

1 of infection. A tolerant plant could present an elevated injury without showing a proportional
2 yield loss.

3 The first step in a breeding program for increasing the level of plant defense to insect
4 attack is to identify sources of defense mechanisms. Several authors have evaluated stem and
5 ear antibiosis of maize to the pink stem borer (Anglade, 1961a; Anglade and Bertin, 1968;
6 Malvar et al., 1993; Cartea et al., 1994; Butrón et al., 1998a, b; Butrón et al., 199-). After
7 identifying the sources of defense mechanisms, it is necessary to study how they are
8 transmitted from the original varieties to improved cultivars to design an efficient breeding
9 program (Pathak, 1991). A study has been carried out to estimate general and specific
10 combining abilities and reciprocal effects for antibiotic resistance of the ear. It has showed
11 that specific combining ability (SCA) effects were not important for grain antibiosis to the
12 pink stem borer (Butrón et al., 1998a). However, there is only one study about transmittability
13 of stem antibiosis (Anglade and Bertin, 1968). They evaluated the antibiotic resistance to pink
14 stem borer of inbred lines and their hybrids and concluded that antibiotic resistant lines
15 transmitted antibiosis to their hybrids.

16 There is only a work about the three mechanisms of defense against *Sesamia*
17 *nonagrioides* (Butrón et al., 1998b). In this work tolerance was an important mechanism of
18 defense, since only a small part of the variation of yield loss could be predicted from the level
19 of antibiosis. This indicated the need of selecting genotypes by a comprehensive measure such
20 as yield loss that combines antibiosis and tolerance. However, Lynch (1980) showed that the
21 high yield losses of certain hybrids were compensated by their high potential yield. So, the
22 evaluation of yield under infestation conditions appears as an important way to estimate the
23 defense level against insect attack. Therefore, the knowledge about combining ability effects
24 for yield loss and yield under infestation conditions and about relationship between combining

1 ability effects for both traits would allow determine the best strategy to improve tolerance to
2 pink stem borer

3 So, the objectives of this work were: i) to estimate GCA, SCA, and R effects for
4 antibiotic resistance of stem, yield and yield loss, using a complete diallel of ten inbreds, and
5 ii) to check the relationships among antibiotic resistance, yield loss, and yield under
6 infestation and no infestation conditions to choose the most useful traits for evaluating the
7 defense against pink stem borer attack.

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Materials and methods

Ten maize inbred lines that showed different degrees of resistance to the pink stem borer attack in a previous study (Butrón et al., 199-) were used as parents of a diallel set of crosses with reciprocals (Table 1). In 1994, the 90 hybrids were obtained from the diallel design. The 90 F₁ single crosses were evaluated with 10 checks in a split-plot where plots were sorted according to a 10 × 10 simple lattice. The whole plots were genotypes and the subplots were treatments, namely either infestation with *Sesamia nonagrioides* or no infestation. The experiment was carried out in 1995 and 1996 in Pontevedra, in the Atlantic coast of Spain (42° 25' N, 4° 57' W and 20 m above sea level). In 1996, successive granular insecticide (tricolorfon 2.5%) treatments were applied on the no infested subplots to guarantee protection against pink stem borer attack. Whole plot consisted of two rows and each of them received randomly one different treatment (infestation or no infestation).

At silking, corresponding subplots were infested with eggs of the pink stem borer. Each one of five plants per subplot received a mass of about 40 eggs of *Sesamia nonagrioides*. The infestation was made according to Anglade's technique (Anglade, 1961) with a modification, eggs were placed between the shank of main ear and the stem, instead of placing them at the third leaf below the main ear. The rearing method of eggs was described by Eizaguirre (1989).

At harvest, yields of infested plants and no infested plants at 140 g Kg⁻¹ moisture content were calculated from the ears of infested and no infested plants, respectively. On the basis of these yields, the percentage of yield loss was computed as:

$$\% \text{yield loss} = (1 - \text{yield of infested plants} / \text{yield of no infested plants}) * 100$$

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Stems of infested plants in each plot were dissected. Data were recorded on number of entry holes, number and length of tunnels, and number of larvae of *Sesamia nonagrioides*. Individual analyses of variance were made for stem damage traits and yield loss according to a lattice design. Repetitions were considered as a random factor and hybrids as a fixed factor. If the efficiency of the lattice design was not at least 110% of the randomized complete block, the combined analysis of variance was analyzed as a randomized complete block design. Combined analysis of variance for yield was computed according to a split-plot design.

In the combined analysis of variance for each trait, the variation due to genotypes was orthogonally divided into checks, hybrids of diallel, and checks *versus* hybrids of diallel. Variation among hybrids of diallel was further partitioned into GCA, SCA, and R effects. Griffing's Method 3, Model I (fixed effects) (Griffing, 1956) was used to determine combining ability and reciprocal effects for antibiotic resistance of stem, yield, and yield loss. The analyses of the diallel design was made using the program DIALLEL Analysis and simulation (Burow and Coors, 1994).

The comparisons of means for GCA, SCA, and R effects were carried out by the Fisher's least significant difference method. The standard errors for GCA, SCA, R, and differences among GCA and SCA effects were calculated according to Griffing (1956).

The simple correlation coefficients between GCA and SCA effects for yield under infestation conditions and yield loss, and between GCA and SCA effects for yield under infestation and no infestation conditions were calculated. Analysis of variance and simple correlation coefficients were made with the SAS package (SAS Institute, 1989).

Results and discussion

The combined analyses of variance for stem damage traits were made according to a randomized complete block design because the lattice analyses did not show a significantly higher efficiency (108, 99, 102 and 109 % for number of holes, number of tunnels, tunnel length and number of larvae of *Sesamia*, respectively).

The combined analyses of variance showed significant differences among hybrids of diallel for number and length of tunnels, and number of larvae of *Sesamia* (Table 2). For stem damage traits, there were significant differences among GCA effects and there were not among SCA and R effects. Then, for stem antibiosis only additive effects were important for this set of lines as it was already pointed out for grain antibiosis (Butrón et al., 1998a). Besides, Anglade and Bertin (1968) showed that resistance to *Sesamia nonagrioides* is transmitted from inbreds to hybrids. On the other hand, most studies carried out for determining the genic control of the antibiotic resistance of maize to other pests showed that it was mainly additive, but with a dominant component (Scott et al., 1964; Chiang et al., 1978; Jennings et al., 1974; Ortega et al., 1980; Kaan et al., 1983; Pathak and Otieno, 1990; Thome et al., 1992). In general, the diallel designs made to determine the inheritance of insect resistance showed significant differences among GCA and SCA (Jennings et al., 1974; Ajala, 1993; Widstrom et al., 1992; Thome et al., 1994) in disagreement with our results, since we showed that GCA effects were the only significant for stem antibiosis to pink stem borer. For all stem damage traits, there were neither significant reciprocal effects nor significant interaction year x reciprocal effects. This means that for the genotypes studied, the cytoplasmic effects were not important in the inheritance of stem resistance to the pink stem borer as it has been already pointed out by other authors for the inheritance of corn earworm

1 resistance (Widstrom, 1972). However, there are other studies that show the existence of
2 reciprocal effects for pest resistance (Khalifa and Drolsom, 1988; Widstrom *et al.*, 1992;
3 Ajala, 1993) and that reciprocal effects are large enough to influence decisions in a breeding
4 program for corn borer resistance (Khalifa and Drolsom, 1988). There was not any significant
5 interaction with years, so the genotypes in these trials had a similar behavior across different
6 environments as it was expected since the evaluations were made in both years under artificial
7 infestation. Since GCA effects were the only significant, a intrapopulational recurrent
8 selection program for stem antibiosis would be useful for reducing the stem damage made by
9 the pink stem borer.

10 The split-plot combined analysis of variance for yield showed significant differences
11 between treatments (data not shown), average yield under infestation conditions (7.65 t ha^{-1})
12 being lower than under no infestation conditions (8.96 t ha^{-1}). The existence of significant
13 interactions hybrids of diallel \times treatments and GCA \times treatments for yield (data not shown)
14 was the cause of carrying out the analysis of variance for yield under infestation and no
15 infestation conditions separately.

16 The combined analyses of variance for yield under infestation and no infestation
17 conditions, and yield loss showed significant differences among GCA effects (Table 2). There
18 were also significant differences among SCA effects for yield of no infested plants, but not for
19 yield under infestation conditions and yield loss. The existence of significant interactions SCA
20 \times year for both traits could have masked the differences among SCA effects for yield of
21 infested plants and yield loss. Reciprocal effects were not significant for both traits. However,
22 the significant interaction R \times year for yield under infestation conditions could be the cause of
23 the lack of differences among R effects for this trait. Individual analyses for yield under

1 infestation and no infestation were computed on account of the significance of these
2 interactions.

3 Individual analysis showed significant differences among GCA effects for yield under
4 infestation and no infestation conditions in both years and for yield loss in 1995 (data not
5 shown). There were also significant differences among SCA effects for yield of no infested
6 plants in both years and for yield of infested plants and yield loss in 1996. Reciprocal effects
7 for yield under infestation and no infestation conditions were only significant in 1995. Then,
8 additive and dominant effects were present in the inheritance of yield loss and yield under
9 infestation and no infestation conditions for this set of inbreds. Thome *et al.* (1994) obtained
10 similar results studying yield under infestation with Southwestern corn borer (*Diatraea*
11 *frugiperda* Dyar) and protected conditions in a diallel set of crosses among maize inbreds.
12 Besides, cytoplasmic effects should be considered to improve yield under infestation and no
13 infestation conditions.

14 The expression of yield under infestation conditions and yield loss have had an
15 important environmental component since the interactions SCA \times year and R \times year were
16 significant for yield under infestation conditions and the interaction SCA \times year was
17 significant for yield loss. Therefore, in a breeding program to improve the yield under
18 infestation conditions or reduce yield loss caused by the pink stem borer evaluations should be
19 made in several environments.

20 The inbreds A509 and F7 showed the best GCA effects for number of holes and tunnel
21 length (Table 3). EP28 and F7 exhibited the most favorable GCA effects for number of
22 tunnels. Finally, the lines A509, EP28, and F7 showed the most negatives values for the GCA
23 for the number of larvae of *Sesamia*. EP42 had significant positive GCA effects for all traits.
24 The lines A661, CM105, EP28, and PB60 had, in general, GCA effects that did not

1 significantly differ from zero. A637 showed unfavorable GCA effects for number of holes and
2 tunnel length and the hybrids of the line EP31 performed worse than the hybrid mean for
3 tunnel length. Therefore, the inbreds A509 and F7 were the best general combiners for stem
4 resistance and EP42 was the worst.

5 Under both infestation conditions inbreds A637, A661 and CM105 showed favorable
6 GCA effects for yield, while A509 and EP31 exhibited unfavorable GCA effects (Table 3).
7 The line A637 did not show favorable GCA effects for the antibiosis of the stem, as it was
8 pointed out, and of the ear (Butrón et al., 1998a), but its hybrids were as productive under
9 infestation conditions as those derived from the inbreds A661 and CM105. On the other hand,
10 the line A509, that transmitted antibiotic resistance to stem attack by the pink stem borer to its
11 hybrids and that did not show unfavorable GCA effects for yield loss, exhibited a significant
12 unfavorable GCA effect for yield under infestation and no infestation conditions. Inbred F7
13 showed good GCA effects for stem antibiosis and yield loss, but did not have significant
14 favorable GCA effects for yield under infestation conditions because its hybrids, in general,
15 showed a low yield under no infestation conditions. The low yield loss suffered by these
16 hybrids did not compensate their low yield under no infestation. So, there were not a good
17 concordance between stem antibiosis and yield under infestation conditions as it was already
18 showed between stem antibiosis and yield loss (Butrón et al., 1998b).

19 The no convenience of using yield loss instead of yield under infestation conditions for
20 evaluating the defense level against pink stem borer attack was supported by the low simple
21 correlation coefficient between GCA effects for yield under infestation conditions and those
22 for yield loss ($r = 0.12$). Inbreds A661 and CM105, in spite of not showing favorable GCA
23 effects for yield loss, had good GCA effects for yield under infestation conditions (Table 3).
24 There was a lack of concordance between the lines that exhibited the most favorable GCA

1 effects for yield under infestation conditions and yield loss and a good concordance between
2 inbreds that showed the best GCA effects for yield of infested plants and no infested plants (r
3 = 0.90*). These results supported the proposals made by Lynch (1980), since the high yield
4 under no infestation conditions of certain hybrids compensated the higher yield loss
5 experimented by them than by others such as those derived from the lines EP28 and F7.
6 Therefore, it is important to consider yield under infestation conditions for breeding maize
7 performance to pink stem borer attack as it has already been proposed for other pests (Klenke
8 et al., 1986; Thome et al., 1994; Anglade et al., 1996).

9 The hybrid A637 × EP42 had significant favorable SCA effects for yield under
10 infestation and no infestation conditions in 1995 (Table 4). Besides, we have already pointed
11 out that the inbred A637 showed a good GCA for yield; then this cross could be used directly
12 by maize growers due to its high yield under infestation and no infestation conditions. This
13 hybrid responds to the heterotic pattern “American dent × European flint” suggested as a
14 interesting heterotic pattern for northwestern Spain conditions (Moreno-González, 1988). The
15 crosses A637 × PB60 and A661 × F7 exhibited significant favorable SCA effects for yield
16 under infestation conditions, but their yield performance under no infestation conditions were
17 not as good as that exhibited by A637 × EP42. There were significant correlation coefficients
18 between SCA effects for yield under infestation conditions and yield loss ($r = -0.75$ in 1995
19 and $r = -0.56$ in 1996). Therefore, SCA effects for yield under infestation conditions and yield
20 loss were related. The hybrid A637 × EP42 showed favorable significant SCA effects for both
21 traits, yield and yield loss under infestation conditions. However, SCA effects for yield under
22 high infestation conditions were little related with SCA effects for yield under no infestation
23 conditions (in 1996 the correlation coefficient between SCA effects for yield of infested and

1 no infested plants was $r = 0.34^*$). Then, it would not be adequate to use the yield of no infested
2 plants as an estimation of yield under infestation conditions.

3 Hybrids A509 × A637, A509 × CM105, A637 × EP31, EP42 × A661, EP28 × CM105,
4 and Z77016 × CM105 showed values for yield under infestation conditions better than those
5 of their corresponding reciprocal crosses (Table 4). Therefore, if these crosses are directly
6 used by maize growers, it will be necessary to use the first line of each cross as the female
7 parent.

8 Based on the evidence that additive gene action is the only component of inheritance
9 of stem antibiosis to *Sesamia nonagrioides* for this set of inbreds, the lines mentioned by their
10 good GCA effects could be used as donors of resistance to make a synthetic population that
11 would respond positively to an intrapopulational recurrent selection program for stem
12 antibiosis. However, from this study it appears that the high level of yield under no infestation
13 conditions conferred a better yield performance under infestation conditions, though high
14 yielding hybrids can suffer higher yield loss and/or higher plant damage. Therefore, breeding
15 for antibiosis could increase the level of maize defense to *Sesamia nonagrioides* attack, but at
16 the end the main criterion of selection to develop genotypes with high level of defense
17 mechanisms should be yield under infestation conditions (Thome et al., 1994). Since GCA,
18 SCA, and R effects were significant for yield under infestation conditions, an interpopulational
19 recurrent selection program for yield under infestation conditions appears as the most efficient
20 program to take advantage of both additive and dominant genetic effects.

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2 populations selected for resistance to insects. *Crop Sci.* 32: 85-89.

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1 Table 1. Germplasm description of ten parental inbred lines used for a diallel crossing design
2 with reciprocals.

4 Inbred lines	Pedigree	Type of germplasm
6 A509	A78 x A109	American dent
7 A637	CO106 x A321	American dent
8 A661	AS-A	American dent
9 CM105	V3 x B14 ²	American dent
10 EP28	AS-D	American dent
11 EP31	Silleda	European flint
12 EP42	Tomiño	European flint
13 F7	Lacaune	European flint
14 PB60	Nostrano dell'Isola	European flint
15 Z77016	Z27 x Z36	European flint

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1 Table 2. Mean squares combined over years of the pertinent sources of variation for four stem damage traits, yield under infestation (I) and no
 2 infestation (N) with pink stem borer, and yield loss from a diallel with reciprocals of ten inbred lines tested in two years.

Sources of variation	df	Number of holes	Number of tunnels	Tunnel length	Number of larvae of <i>Sesamia</i>	Yield		Yield loss
						I	N	
Hybrids of diallel (H)	89	15,66	1,03 **	413,61 **	1,92 **	4.12	5.90**	254.06
GCA	9	56,30 **	3,61 **	2067,11 **	8,73 **	16.29**	32.42**	586.68**
SCA	35	12,20	0,68	262,24	1,23	4.11	4.68**	295.58
R	45	10,21	0,79	200,65	1,09	1.70	1.53	155.24
Years x H	89	12,40	0,64	230,76	1,17	3.16**	1.70*	300.19*
Years x GCA	9	6,80	0,81	405,00	1,18	2.34	2.32	229.82
Years x SCA	35	11,25	0,45	153,94	0,91	3.35*	1.39	387.02**
Years x R	45	14,41	0,75	255,65	1,38	3.20*	1.82	246.74
Error	198 [†]	12,92	0,67	270,38	1,36	2.01	1.22	214.35

1 *,** Significant at the 5 and 1% level of probability, respectively.

2 † For yield under no infestation conditions and yield loss, freedom degrees were 178 and, for yield under infestation conditions, they were 177.

1 Table 3. GCA estimates for four stem damage traits, yield of infested and no infested plants, and yield loss from a diallel with reciprocals of
 2 ten inbred lines tested in two years.

4					Number of	Yield	Yield	
5		Number	Number	Tunnel	larvae of	of infested	of no infested	Yield
6	Inbred line	of holes	of tunnels	length	<i>Sesamia</i>	plants	plants	loss
8	A509	-1.2*	-0.2	-5.3*	-0.4*	-0.5*	-0.8*	-0.9
9	A637	1.0*	0.0	7.2*	-0.1	0.5*	0.6*	0.7
10	A661	0.4	0.2	-3.0	0.2	0.6*	0.8*	1.3
11	CM105	-0.7	0.1	-2.5	0.0	0.7*	1.1*	2.5
12	EP28	-0.5	-0.3*	-0.9	-0.5*	0.3	0.0	-3.7*
13	EP31	0.7	0.2	4.1*	0.2	-0.8*	-0.9*	0.1
14	EP42	1.5*	0.4*	10.0*	0.7*	0.1	0.2	1.1
15	F7	-1.2*	-0.3*	-8.2*	-0.3*	-0.1	-0.7*	-6.4*

1	PB60	0.5	0.0	1.5	0.3*	-0.1	0.4*	4.1*
2	Z77016	-0.5	-0.1	-2.9	-0.1	-0.6*	-0.6*	1.3
3	LSD (5%)	1.2	0.2	5.7	0.4	0.5	0.4	5.1

4

5 * GCA estimate differed significantly from zero.

1 Table 4. Specific combining ability (SCA) and reciprocal effects (R) of diallel crosses among
 2 ten inbred lines for maize yield under infestation (I) and no infestation (N) conditions and for
 3 yield loss in 1995 and 1996.

	1995						1996				
	SCA			R			SCA			R	
	Yield		Yield	Yield		Yield	Yield		Yield	Yield	
	I	N	loss	I	N	I	N	loss	I	N	
10	A509 × A637	-0.10	0.10	3.2	2.32*	1.82*	0.56	-0.43	-9.8	-0.41	-0.19
11	A509 × A661	-0.13	0.04	2.0	-0.09	-0.25	-0.75	-1.34*	-4.2	0.25	0.18
12	A509 × CM105	0.81	0.47	-4.7	1.53*	0.43	-0.60	0.19	8.9	-0.91	-0.48
13	A509 × EP28	-0.49	-0.10	5.2	0.78	0.59	-0.04	0.31	2.0	0.28	-0.85
14	A509 × EP31	0.66	0.00	-10.4	0.94	0.24	0.18	0.19	-1.5	-0.39	0.25
15	A509 × EP42	0.36	0.47	1.1	-1.49	-1.03	-0.51	-0.21	4.0	0.79	0.36
16	A509 × F7	-0.97	0.02	12.3	0.77	0.69	1.02	0.94	-2.8	-0.32	0.28
17	A509 × PB60	-0.37	-0.68	-2.2	0.40	0.65	0.00	-0.42	-1.5	-0.43	-0.81
18	A509 × Z77016	0.22	-0.32	-6.4	-1.41	-0.72	0.14	0.77	4.9	-0.16	0.38
19	A637 × A661	-0.36	0.00	2.7	-1.07	0.27	-0.37	0.27	5.0	0.12	-0.22
20	A637 × CM105	-2.70*	-0.98	20.8	-0.37	-0.71	-0.03	-0.22	-1.0	0.15	0.69
21	A637 × EP28	-0.32	-0.65	-4.7	-0.37	0.36	-1.15	-1.03*	2.6	1.04	0.46
22	A637 × EP31	-0.79	-0.31	10.7	1.74*	0.77	0.04	-0.01	2.0	-1.42	-1.30
23	A637 × EP42	2.66*	1.65*	-13.1	0.14	-0.13	0.97	-0.59	-14.5*	-0.78	-0.09

1	A637 × F7	-0.17	0.41	6.7	1.06	0.13	-0.14	0.51	6.2	0.55	0.38
2	A637 × PB60	1.39*	0.49	-12.1	1.07	-0.30	-0.26	0.86	7.7	0.68	-0.54
3	A637 × Z77016	0.40	-0.72	-14.2	0.57	0.20	0.36	0.65	1.7	0.98	0.09
4	A661 × CM105	1.02	0.15	-10.1	0.62	0.18	-0.15	-0.64	-3.0	-0.11	0.72
5	A661 × EP28	-1.02	-1.79*	-8.3	0.45	0.95	-0.04	-1.17*	-10.3	-0.06	-0.56
6	A661 × EP31	-1.27	-1.21*	6.5	-0.59	-0.52	0.58	-0.58	-10.0	-0.16	0.01
7	A661 × EP42	-0.45	0.44	8.7	-1.89*	-1.37*	-0.25	1.36*	13.4*	-0.09	-0.23
8	A661 × F7	1.51*	1.26*	-3.6	-0.67	-0.62	0.88	0.88	-0.2	0.30	0.09
9	A661 × PB60	0.72	1.00*	-0.1	0.06	0.94	-0.45	0.78	10.7	0.44	0.89
10	A661 × Z77016	-0.01	0.10	2.3	0.65	-0.17	0.55	0.45	1.5	-0.26	0.25
11	CM105 × EP28	0.55	0.27	-1.6	-2.13*	-1.07	0.51	-0.08	-7.1	0.63	0.17
12	CM105 × EP31	-0.92	-0.48	5.7	-0.34	-0.55	0.32	-1.72*	-22.4*	-0.14	-0.75
13	CM105 × EP42	0.04	-0.23	-3.9	0.39	0.66	-0.93	0.69	15.1*	0.16	0.24
14	CM105 × F7	1.16	0.76	-5.3	-0.59	-0.22	0.74	1.15*	3.3	0.33	0.60
15	CM105 × PB60	-0.44	-0.63	-1.9	1.18	1.05	-0.23	0.33	6.3	-0.75	0.12
16	CM105 × Z77016	0.48	0.67	0.9	-2.03*	-1.51*	0.38	0.31	-0.2	0.56	0.64
17	EP28 × EP31	-0.55	-0.03	8.6	0.53	0.49	0.13	0.44	3.1	-0.06	0.09
18	EP28 × EP42	0.22	0.76	4.9	-0.09	-0.28	0.61	0.52	-1.1	-0.23	-0.57
19	EP28 × F7	-0.22	-0.09	1.2	-0.09	0.58	0.47	0.58	0.1	0.25	0.08
20	EP28 × PB60	0.89	0.43	-6.3	-0.35	0.05	-1.10	-0.51	8.7	0.80	0.26
21	EP28 × Z77016	0.94	1.20*	1.1	0.56	0.97	0.61	0.93	1.9	0.76	0.50
22	EP31 × EP42	0.01	-0.35	-4.6	-0.47	0.58	0.82	0.44	-4.2	-0.37	0.10
23	EP31 × F7	0.89	0.44	-8.0	-0.15	-0.19	-0.83	0.37	14.3*	0.36	0.09

1	EP31 × PB60	0.71	1.06*	2.3	-0.80	-0.41	-0.49	0.63	7.1	0.72	-2.19
2	EP31 × Z77016	1.27	0.89	-10.8	0.49	0.75	-0.76	0.24	11.7*	0.18	-0.04
3	EP42 × F7	-0.30	-0.91	-7.7	0.27	-0.23	-0.67	-1.25*	-5.9	-0.50	-0.32
4	EP42 × PB60	-1.95*	-1.22*	13.2	0.21	0.56	0.23	-0.40	-4.0	0.25	-0.30
5	EP42 × Z77016	-0.58	-0.62	1.5	-1.04	-0.27	-0.27	-0.57	-2.7	-0.57	-0.52
6	F7 × PB60	-0.06	-0.56	-7.1	-0.34	0.29	0.92	-0.83	-17.0*	0.16	-0.29
7	F7 × Z77016	-1.83*	-1.32*	11.5	0.33	0.04	-2.40	-2.36*	2.1	-0.80	-0.42
8	PB60 × Z77016	-0.89	0.12	14.2	-1.20	-1.59*	1.38	-0.43	-18.0*	-0.37	0.08
9	LSD (SCA _{ij} - SCA _{ik})	2.01	1.48					1.44	17.5		
10	LSD (SCA _{ij} - SCA _{kl})	1.86	1.37					1.34	16.2		

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12 * Estimate differed significantly from zero.