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Combining Ability Studies over Environments in High Altitude Elite Inbred Lines of Maize (*Zea mays* L.)

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Abstract – **The experimental material comprised of 66 F1's generated by crossing twelve diverse inbred lines of maize(*Zea mays* L.) in a half diallel fashion and their parents were evaluated in RBD in two replications at two locations during Kharif, 2008. The pooled analysis revealed that both *gca* and *sca* were influenced by environments, which suggested that studies are being conducted over the environments to get unbiased estimates. The sca x e interaction was greater than gca x e interaction for most of the traits. The compassion of relative magnitude of gca and sca variances indicated greater magnitude of sca variances for all the traits, indicating greater importance of non additive gene action for the inheritance of these traits. PMI-298, PMI-67, PMI-69, PMI-117, PMI-224 and PMI-118 were best general combiners for grain yield and yield attributing traits. The most promising crosses, in order of merit for grain yield, were PMI-67 × PMI-69, PMI-48 × PMI-224, PMI-360 × PMI-401, PMI-118 × PMI-360, PMI-03 × PMI-64, PMI-64 × PMI-67, PMI-64 × PMI-118, PMI-117 × PMI-298, PMI-224 × PMI-298, PMI-117 × PMI-360, PMI-224 × PMI-298, PMI-117 × PMI-360 and PMI-69 × PMI-401. The result of the present investigation revealed that in general there was no relationship between GCA effects of the parents and the SCA effects of the single crosses. However mean performance of single crosses was largely dependent upon the mean performance of the parents involved so high gca value of parents is no guarantee of high SCA effects of their crosses.**

Keywords – **Combining Ability Over Environments, Diallel, Gene Action, *Zea mays* L.**

I. INTRODUCTION

Maize (*Zea mays* L.) belonging to the monocot family poaceae, is the third most important crop of world after rice and wheat but ranks first with respect to production and productivity. About 2/3 of this area is in developing countries, where maize is widely grown for human consumption. Besides human food it has emerged as an important crop to be used as animal feed and a source of large number of industrial products. Being a C_4 plant, it is physiologically more efficient and has higher grain yield potential as compared to rice and wheat, so called as Queen of cereals. Maize gives highest conversion of dry substance to meat, milk and eggs as compared to other cereal grains. Maize has acquired a well-deserved reputation as a staple cereal food. With its high carbohydrates, fats, protein, some of vitamins and minerals, it is nutritious for human consumption. That is why maize has now been termed as nutricereal. The presence of a mixture of carotenoids (β carotene, cryptoxanthins and β-zeacarotene having Pro-Vitamin A activity) provides maize a specific place among cereals. In India maize is cultivated over an area of 8.22 million hectares with annual production of about 22.30 million tonnes and average productivity of 2700 kgs per hectare [1]. Maize crop due to wide adaptability is grown over diverse environmental and geographical range, as compared to any other cereal crop , extending from 58° N to 40° S and in areas below sea level in the Caspian plains to the altitude of more than 3900 m in the Peruvian Andes. The demand of maize is expected to rise dramatically in the next two decades by 2020 AD and in developing nations maize demand will surpass the demand for both rice and wheat production[2]. Now it has been established beyond doubt that hybrids maintain yield advantage over OPVs in both favourable and unfavourable environments and as a mater of fact the yield advantage is more striking under stressed growing conditions. Therefore, hybrid technology provides an excellent option to enhance production and productivity of maize under high altitudes temperate conditions.

II. MATERIALS AND METHODS

The present study was carried out at two locations viz., Experimental Farm of the Division of Plant Breeding and Genetics, SKUAST-K, Shalimar Srinagar and High Altitude Rice Research Sub-station Larnoo. Twelve phenotypically diverse, vigorous and productive advanced maize inbred lines viz. PMI-03, PMI-48, PMI-64, PMI-67, PMI-68, PMI-69, PMI-117, PMI-118, PMI-224, PMI-298, PMI-390 and PMI-401 developed and maintained at High Altitude Maize Research Station, Sagam were crossed in a diallel fashion in all possible combinations without reciprocals to generate sixty six F_1s cross combinations. . The 66 F1's and 12 parents were evaluated in RBD with two replications at each location during Kharif, 2008.The experimental material therefore comprised 12 parental lines their 66 F_1s cross combinations and two check varieties C15 and W3 x W5. . Each progeny was grown with inter and intra spacing of 60 and 20 cm, respectively. The observations were recorded on five competent plants for different traits namely, ear length, ear girth, kernel row number per ear, kernels per row, grain depth, shelling percentage, 100 grain weight (g), grain yield per plant (g) and protein content (%). The protein was estimated according to the modified Kjeldhal's method of Piper [3]. The estimates of variance for both the general and specific combining abilities and their effects were computed according to Models I (fixed effect model) and method II (parents and crosses, excluding reciprocals) as given by Griffing [4]. The combining ability analysis over environments was done following the method given by Singh [5].

Table I: Analysis of variance for yield, yield attributing traits in maize (Zea.mays L.) pooled-over environments

S. No.	Source of Variation	d.f	Ear length (cm)	Ear girth (cm)	Kernel row number per ear	Kernels per row	Grain depth (cm)	Shelling percentage	100-grain weight (g)	Grain yield per plant (g)
1.	Environments	1	394.875**	87.789**	0.185	1409.300**	0.118**	0.438	148.281**	39536.790**
2.	Block within Environments	2	1.7895*	0.068	0.939	5.319	0.000	0.405	0.033	145.160**
3.	Treatments	77	17.362**	4.377**	10.748**	86.735**	0.054**	25.259**	60.830**	3572.761**
4.	Parents	11	8.063**	2.717**	15.233**	56.625**	0.030**	28.130**	41.460**	916.769**
5.	Hybrids	65	6.919**	2.446**	9.481**	56.625**	0.030**	25.009**	41.460**	1467.798**
6.	Parents v. s Hybrids	1	798.409**	148.175**	43.751**	3650.500**	1.681**	9.909**	1555.938**	169611.300**
7.	Treatment x Environments	77	5.174**	1.422**	1.916**	19.853**	0.003**	1.789**	5.253**	391.461**
8.	Parent x Environments.	11	1.055*	0.471*	0.305	7.590**	0.002**	2.032**	2.258**	39.016
9.	Hybrids x Environments	65	5.041**	1.496**	2.178**	18.992**	00004**	1.647**	5.691**	374.551**
10.	Parent v. s Hybrids x Environments	1	59.116**	7.083**	2.647**	210.735**	0.011**	8.338**	9.663**	53678.475**
11.	Error	154	0.491	0.237	0.354	1.908	0.000	0.550	0.901	27.189
	Total	311	7.104	1.836	3.318	31.901	0.015	6.937	17.285	1123.020

*, ** significant at 5 and 1 per cent level, respectively.

III. RESULTS AND DISCUSSION

The pooled analysis over the environments (Table 1) revealed highly significant differences among genotypes for all the characters under study indicating thereby presence of considerable amount of genetic variability significant, the parents and crosses interacted differentially for the traits under study in different environments. Mean sum of square for two locations and G × E interaction were also highly significant for all the characters. The analysis of variance for combining ability over environments revealed that mean square due to GCA and SCA were highly significant for all the characters studied. Significant GCA × environment and SCA × environment mean squares were observed for all traits except proficiency index suggesting that GCA and SCA were influence by environment. The significance of the interaction arising from *gca* and *sca* with the environments, revealed that the alleles controlling the *gca* and *sca* behaved differently in the different environments. The presence of significant combining ability effect x environmental interaction has been reported for grain yield and component traits in maize by various workers [6], [7]. Detection of genotype × environment interactions for various traits in the present study emphasize multi environment testing of genetic material to help to draw valid conclusion and identify cultivars for specific agro ecological situations. The estimates of variance due to dominance deviation ($\square^2_D$) values were much higher than the corresponding additive genetic variance ($\square^2_A$) thus indicating preponderance of non-additive gene action as compared to additive gene action in individual environments as well as pooled analysis for all the traits under study. Importance of non-additive gene action for yield and yield related traits have been reported by various workers [8] - [10].The prevalence of greater magnitude of non additive genetic component of variance relative to additive component favour the hybrid production. However, the average degree of dominance was in the range of over-dominance for all the traits studied (Table II).

Table II: Analysis of variance for combining ability and estimates of components of variance for yield, yield attributing traits in maize (Zea.mays L.) pooled-over environments

S. No.	Source of variation	d.f	Ear length (cm)	Ear girth (cm)	Kernel row number per ear	Kernels per row	Grain depth (cm)	Shelling percentage	100 grain weight (g)	Grain yield per plant (g)
1.	GCA	11	11.685**	5.179**	25.378**	76.946**	00.057**	40828**	96.032	2510.533**
2.	Sca	66	8.180**	1.6909**	2.040**	34.771**	0.022**	7.929**	19479**	1655.689**
3.	Environments	1	197.438**	43.896**	0.093	704.650**	0.059**	0.219	74.141**	19768.390**
4.	GCA x Environments	11	2.372**	0.679**	1.146**	11.863**	0.003**	0.869	6.565**	291.778**
5.	SCA x Environments	66	2.623**	0.717**	0.927**	9.604**	0.002**	1.043	1.970**	179.722**

6.	Error	154	0.246	0.118	0.117	0.954	0.001*	0.275	0.451	13.594
7.	σ2g		0.409	0.181	0.900	2.174	0.002	1.448	3.414	89.176
8.	σ2s		3.967	0.786	0.931	18.408	0.011	3.827	9.514	826.047
9.	σ2l		2.988	0.663	0.001	10.662	0.001	0.001	1.117	299.315
10.	σ2gl		0.152	0.040	0.069	0.779	0.001	0.054	0.437	19.870
11.	σ2sl		2.377	0.598	0.750	8.650	0.001	0.594	1.519	166.128
12.	σ2A		0.817	0.361	1.800	5.428	0.004	2.896	6.827	178.353
13.	σ2D		3.967	0.786	0.931	18.408	0.011	3.827	9.541	826.047
14.	$\left(\frac{\sigma 2D}{\sigma 2A}\right)^{1/2}$		2.201	1.470	0.749	1.842	1.658	1.154	1.182	2.150

None of the parents was found to be a good combiner for all the characters but PMI-67 revealed significant GCA effect in desired direction for grain yield per plant, 100 grain weight, ear girth and grain depth (Table II). Further PMI-298 was best general combiner for grain yield per plant and high protein content followed by PMI-67, PMI-69, PMI-117, PMI-224 and PMI-118 High combining ability for grain yield was associated with high combining ability for yield component traits viz, 100-grain weight, grain depth, ear girth, kernel row^{-1} and number of kernel row per ear. For various traits desirable significant GCA effect of parents was strongly associated with average to high *per se* performance. These promising parental lines need to crossed to other elite genetic material to broaden genetic base of resulting crosses and segregating generations. The lines with desirable GCA effects for grain yield and yield contributing traits could be crossed inter-se to constitute base population and subsequent recurrent selection efforts would facilitate derivation of lines excelling in maximum desirable character.

Further study revealed that there has been no correlation between grain yield and desirable *sca* effect for quality, as most of the cross combinations exhibiting desirable sca effect for quality revealed non-significant effect of *sca* for grain yield per plant. The study of SCA effect on pooled analysis revealed that none of the crosses was good specific combiner for all the traits under study (Table III). However, several cross combinations were observed to have highest desirable significant SCA effects for these traits.

Thirty four out of sixty six cross combination showed desirable significant SCA effects for most important trait i.e grain yield per plant. The best cross combination for this trait was PMI-67 x PMI-69 showing excellent SCA effect (44.83) and this cross was a good specific combination for ear length , ear girth , grain depth , kernel row number ear^{-1} and kernel per row . The other top ranking crosses for grain yield per plant included PMI-48 x PMI-224 , PMI-360 x 401 , PMI-118 x PMI-360, PMI-03 x PMI-64 , PMI-64 x PMI-67 , PMI-64 x PMI-118, PMI-117 x PMI-298, PMI-224 x PMI-298, PMI-117 x PMI-360 and PMI-69 x PMI-401 and on basis of mean per se performance the desirable crosses were PMI-117 x PMI-298, PMI-67 x PMI-69, PMI-224 x PMI-298, PMI-118 x PMI-298 and PMI-64 x PMI-67.. The high *per se* performance in general was strongly associated with specific combining ability [11]. Protein content among top ranking crosses for grain yield per plant was lowest for PMI-03 x PMI-64 (7.70%) and highest for PMI-224 x PMI-298 (12.30%) and while assessing the performance of parents on the basis of their general combining ability, it was observed that most desirable specific cross combination for grain yield per plant were the result of crosses between high x average or low x low or low x high general

combiners (Table IV). The perusal of results indicated that superior crosses for different traits involved all types of combiner, which was reported by several workers in most of the crop species. Dass *et al*,[12] concluded that good cross combination is not always result of result of high x high general combiners. Labna *et al*[13] suggested that manifestation of high SCA effects in some cross combination results in the concentration of more favourable genes and their interaction by the parents that usually are high or average general combiners . The superiority of crosses involving high x high, high x average and average x average combiners as parents might have possibly resulted from the concentration and interaction of favourble alleles contributed by parents. The crosses could be exploited for isolation of pure lines through pedigree method of breeding involving progeny testing, since that non additive component is predominant. The superiority of crosses involving high x low or average x low combiners as parents could be explained on the basis of interaction between positive alleles from good/average combiners and negative alleles from the poor combiners as parents [14]. The high yield of such crosses would be non-fixable and thus could be exploited for heterosis breeding. The superior cross combination involving low x low general combiners could result from over dominance and epistasis[15] . The crosses between good and poor general combiners resulting in significant sca effects could be used to throw superior transgressive segregants when the additive gene effects of the parents and the complimentary epistatic effects in crosses act in the same direction to maximize the desirable plant attributes.

Table III: Effects of general combining ability on yield and yield attributing traits in maize (Zea.mays L.) pooled-over environments

S.No.	Pedigree	Ear length (cm)	Ear girth (cm)	Kernel row number per ear	Kernels per row	Grain depth (cm)	Shelling percentage	100 grain weight (g)	Grain yield per plant (g)
1.	PMI-03	-0.024	0.016	0.354**	-1.088**	-0.065**	-2.247**	-1.366**	-8.764**
2.	PMI-48	-0.952**	-0.757**	-0.401**	-2.929**	-0.059**	-0.441**	-1.155**	-18.159**
3.	PMI-64	-0.095	0.251**	0.942**	0.492**	-0.017**	-1.504**	-1.958**	-0.860*
4.	PMI-67	-0.068	0.618**	0.038	0.147	0.066**	-0.445**	1.623**	8.540**
5.	PMI-68	0.360**	0.439**	-1.239**	-0.140	0.052**	0.307**	3.773**	6.684**
6.	PMI-69	-0.676**	-0.249**	0.099	-1.653**	-0.033**	0.644**	-0.866**	-6.993**
7.	PMI-117	-0.042	0.269*	0.413**	0.815**	0.030**	0.571**	-0.486**	5.773**
8.	PMI-118	0.119	-0.016	-0.040	1.401**	0.004	1.684**	-0.514**	4.107**
9.	PMI-224	0.289**	-0.356**	0.490**	2.369**	0.045**	2.100**	-1.259**	4.668**
10.	PMI-298	1.673**	0.323**-	-1.035**	2.612**	0.037**	-0.050	3.042**	15.249**
11.	PMI-360	-0.381**	0.153*	1.877**	-1.424**	-0.041**	-0.129	-1.251**	0.206
12.	PMI-401	-0.202*	-0.659**	-1.498**	-0.601**	-0.019**	-0.490	0.418**	-10.410**
S.E. (g i)		+ 0.0589	+ 0.062	+ 0.076	+ 0.176	+ 0.002	+ 0.002	+ 0.121	+ 0.667
S.E. (gi—gj)		+ 0.132	+ 0.091	+ 0.112	+ 0.261	+ 0.004	+ 0.004	+ 0.179	+ 0.985
No. of parents showing desirable gca effects		3	6	5	5	5	5	4	6

*, ** significant at 5 and 1 per cent level, respectively.

IV. CONCLUSION

Thus the result of the present investigation revealed that in general there was no relationship between GCA effects of the parents and the SCA effects of the single crosses. However mean performance of single crosses was largely dependent upon the mean performance of the parents involved so high gca value of parents is no guarantee of high SCA effects of their crosses and the selection of parents should be based on specific combing ability tests. The superior most single cross combinations that suppressed better check by significant margin for grain yield per plant merits consideration for extensive testing to verify its suitability from commercial exploitation.

Table 4: Estimates of specific combining ability effects for grain yield and other characters in maize. (*Zea.mays* L.) pooled-over environments

S.No.	***Crosses***	**Ear length (cm)**	**Ear girth (cm)**	**Kernel row number per ear**	**Kernels per row**	**Grain depth (cm)**	**Shelling percentage**	**100 grain weight (g)**	**Grain yield per plant (g)**
1	**PMI-03 x PMI-48**	3.037**	-0.331	-0.431	4.419**	-0.006	1.344**	1.782**	18.663**
2	**PMI-03 x PMI-64**	0.430	1.555**	0.826*	3.197**	0.106**	2.031**	1.780**	27.609**
3	**PMI-03 x PMI-67**	2.153**	1.564**	0.880*	2.542**	0.056**	-1.103*	-0.761	14.836**
4	**PMI-03 x PMI-68**	1.100*	0.617	0.406	0.180	0.053**	-1.505**	2.172**	13.212**
5	**PMI-03 x PMI-69**	0.760	-0.320	-0.531	0.242	-0.087**	-2.092**	4.308**	15.769**
6	**PMI-03 x PMI-117**	-0.249	0.162	0.605	-0.076	-0.018	0.231	-0.247	1.863
7	**PMI-03 x PMI-118**	0.341	0.073	0.258	-0.321	-0.017	-1.206*	-0.726	-6.041
8	**PMI-03 x PMI-224**	-0.204	-0.338	2.078**	-0.779	0.025	1.752**	-2.192**	-4.167
9	**PMI-03 x PMI-298**	1.912	-0.141	-1.322**	3.278**	0.037	0.152	-0.865	-2.607
10	**PMI-03 x PMI-360**	0.716	0.153	-0.860*	3.913**	0.008	-0.669	-1.262	0.018
11	**PMI-03 x PMI-401**	0.287	0.091	-0.135	1.340	0.033*	-0.283	0.406	4.909
12	**PMI-48 x PMI-64**	0.859	0.671*	1.081**	3.313**	0.016	-1.426**	-1.423	7.847*
13	**PMI-48 x PMI-67**	-1.918**	0.805*	0.585	-2.417*	0.048*	1.242*	0.339	-7.396*
14	**PMI-48 x PMI-68**	-0.472	0.109	-0.488	-2.579**	0.014	-1.485**	0.609	-9.200*
15	**PMI-48 x PMI-69**	-0.436	-0.329	0.374	0.333	-0.038**	0.352	-2.125**	-6.760
16	**PMI-48 x PMI-117**	0.555	0.153	0.610	-2.285*	-0.007	1.051*	0.750	3.171
17	**PMI-48 x PMI-118**	0.894	-0.311	-0.837*	2.180*	-0.010	-0.937	1.458*	1.455
18	**PMI-48 x PMI-224**	0.475	0.028	1.133**	3.662**	0.104	2.447**	3.703**	41.989
19	**PMI-48 x PMI-298**	0.341	0.475	-0.692	0.569	-0.004	-1.103*	3.327**	-1.152
20	**PMI-48 x PMI-360**	0.769	0.644	0.746	2.705**	0.043**	-1.274*	-0.325	10.524**
21	**PMI-48 x PMI-401**	1.216*	0.707*	0.671	2.681**	0.153**	0.061	-0.057	13.959**
22	**PMI-64 x PMI-67**	1.225*	-0.204	-0.908*	3.212**	-0.052**	-0.571	4.086**	27.365**
23	PMI-64 x PMI-68	0.296	-0.525	-0.831*	0.149	0.007	0.577	-0.146	-6.607

24	**PMI-64 x PMI-69**	-0.981	-0.463	0.231	-2.538**	-0.090**	-1.585**	-1.383*	-12.910**
25	**PMI-64 x PMI-117**	2.448**	0.394	1.867**	2.894**	0.086**	-0.937	0.422	24.754**
26	**PMI-64 x PMI-118**	0.787	0.555	0.771	0.858	0.135**	0.951	3.118**	25.910**
27	**PMI-64 x PMI-224**	-0.508	1.019**	0.440	-2.710**	0.081**	1.535**	-1.842**	-18.631**
28	**PMI-64 x PMI-298**	-0.516	-0.159	0.415	-1.153	0.004	-0.865	0.780	6.519
29	**PMI-64 x PMI-360**	0.787	-0.260	-0.547	1.433	0.003	-1.287*	-1.030	-4.616
30	**PMI-64 x PMI-401**	1.359**	-0.177	-0.922*	2.810**	-0.117**	-1.701**	0.626	5.065
31	**PMI-67 x PMI-68**	-0.981*	-0.516	1.622**	1.144	-0.073**	-2.106**	-1.904**	1.910
32	**PMI-67 x PMI-69**	3.305**	1.546**	2.835**	6.306**	0.145**	-0.618	1.223*	44.835**
33	**PMI-67 x PMI-117**	1.921**	0.028	-1.179**	2.888**	0.048**	-0.721	4.852**	20.452**
34	**PMI-67 x PMI-118**	1.510**	0.189	-0.476	4.953**	-0.005	-0.358	-0.585	14.055**
35	**PMI-67 x PMI-224**	1.466**	0.778*	-0.256	1.735	0.009	-0.374	-1.153	0.924
36	**PMI-67 x PMI-298**	1.582*	-0.025	-0.481	1.842	0.031*	-0.774	-0.071	5.031
37	**PMI-67 x PMI-360**	-1.115*	-0.481	0.106	-3.172**	0.078	-0.296	1.725**	-4.566
38	**PMI-67 x PMI-401**	0.957*	0.207	-0.019	1.155	0.083**	-0.790	2.838**	17.747**
39	**PMI-68 x PMI-69**	1.126**	0.475	-0.538	-1.306	0.048**	-1.671**	5.144**	7.271*
40	**PMI-68 x PMI-117**	0.117	0.487	0.197	2.726**	0.072**	-1.573**	-0.556	10.597**
41	**PMI-68 x PMI-118**	2.082**	0.992**	0.451	4.790**	0.053**	-0.110**	-0.132	20.624**
42	**PMI-68 x PMI-224**	0.662	0.457	-0.054	1.772	0.058**	-0.101	3.000**	16.367**
43	**PMI-68 x PMI-298**	-0.097	0.528	1.096**	1.130	0.068**	-1.276*	0.392	11.437**
44	**PMI-68 x PMI-360**	1.082*	0.323	-0.017	3.465**	0.004	-1.648*	1.172	20.322**
45	**PMI-68 x PMI-401**	0.403	0.510	0.842*	1.967*	0.016	-2.613**	3.438**	14.365**
46	**PMI-69 x PMI-117**	-0.097	0.019	0.860*	2.228*	0.042**	-1.665**	-0.030	10.413**
47	**PMI-69 x PMI-118**	0.992*	0.930**	0.137	3.353**	0.131**	-2.948**	1.369*	17.206**
48	**PMI-69 x PMI-224**	0.823	-0.106	0.133	3.985**	0.013	1.961**	-0.251	11.005**
49	**PMI-69 x PMI-298**	-0.061	0.966**	2.658**	-1.208	0.140**	3.336**	1.800**	25.307**
50	**PMI-69 x PMI-360**	0.742	0.385	-1.254**	0.828	0.099**	0.565	2.391**	5.622
51	**PMI-69 x PMI-401**	0.439	0.073	-0.979*	-0.095	0.001	-1.749**	1.219	-5.439
52	**PMI-117 x PMI-118**	1.109*	0.622	0.078	2.235*	0.030*	-0.949	1.716**	12.088**
53	**PMI-117 x PMI-224**	0.689	0.751*	-2.543**	-0.033	0.029*	-3.065**	1.456*	0.354
54	**PMI-117 x PMI-298**	2.180**	0.323	-0.356	4.624**	0.079**	1.385**	2.155**	25.891**
55	**PMI-117 x PMI-360**	0.359	0.867**	0.831*	1.960*	0.083**	0.688	1.644*	25.479**
56	**PMI-117 x PMI-401**	0.930	0.430	1.156**	2.787**	0.093**	-0.851	0.106	14.605**
57	**PMI-118 x PMI-224**	0.278	-0.338	0.672	1.228	0.051**	1.822**	0.772	12.510**
58	**PMI-118 x PMI-298**	1.019*	-0.016	-0.253	2.238*	0.118**	3.172**	3.374**	21.927**
59	**PMI-118 x PMI-360**	0.823	0.403	-0.015	4.274**	0.012	3.501**	2.039**	28.215**
60	**PMI-118 x PMI-401**	-0.231	1.216**	0.910*	-0.348	0.099**	0.536	0.792	1.678
61	**PMI-224 x PMI-298**	1.600**	0.573	-0.233	1.021	0.075**	1.881**	3.803**	25.526**
62	**PMI-224 x PMI-360**	-0.847	-0.633	-0.295	0.056	0.006	0.585	1.152*	3.109
63	**PMI-224 x PMI-401**	0.100	0.055	-0.370	0.683	-0.109**	3.695**	1.614*	6.135
64	**PMI-298 x PMI-360**	1.269**	0.189	0.280	1.363	-0.084**	2.890**	-2.167**	1.573
65	**PMI-298 x PMI-401**	0.591	-0.249	-0.095	0.840	-0.064**	3.230**	-0.354	-2.351
66	**PMI-360 x PMI-401**	1.769**	0.671*	0.192	1.676*	0.022**	-2.451**	4.427**	28.572**
	SE (Sij)	**± 0.326**	**± 0.226**	**± 0.277**	**± 0.643**	**±0.010**	**±0.345**	**±0.442**	**±2.249**
	S.E. (Sij-Sik)	**± 0.477**	**± 0.331**	**± 0.405**	**± 0.941**	**±0.014**	**±0.505**	**±0.646**	**± 0.941**
	No. of croses showing desirable sca effects	**23**	**15**	**13**	**30**	**33**	**19**	**28**	**35**

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